Submitted to

US Army Corps of Engineers
Walla Walla District

Salmon Decision Analysis
Lower Snake River Feasibility Study

FINAL REPORT

Submitted by

HARZA NORTHWEST, INC.

October 4, 1996

DEPARTMENT OF THE ARMY
WALLA WALLA DISTRICT, CORPS OF ENGINEERS
201 NORTH THIRD AVENUE
WALLA WALLA, WASHINGTON 99362-1876

Reply To
Attention Of:

November 14, 1996

Planning Division

Dear Interested Party:

The enclosed report is provided in response to your request for the "HARZA Report". The Salmon Decision Analysis, Lower Snake River Feasibility Study, Final Report was prepared by HARZA Northwest, Inc., Portland, Oregon, under contract with the Corps of Engineers. The purpose of the contract with HARZA was to develop a decision analysis process regarding the feasibility of salmon recovery measures, including reservoir drawdown, on the lower Snake River. HARZA was allowed a significant level of independence in development of this report. As such, the content and conclusions of the analysis in their report do not necessarily reflect the position or policies of the Corps of Engineers.

The Walla Walla District is preparing an interim status report for the Lower Snake River Juvenile Salmon Migration Feasibility Study. The Interim Status Report, scheduled for public release in November 1996, addresses salmon recovery options on the lower Snake River. The HARAZA report provides information and an analysis process that may be considered in development of that report and our ongoing feasibility study.

If you have any questions regarding the HARZA report please contact me at 509-527-7241 or Mr. Pete Poolman of my Planning Division staff at 509-527-7261.

Sincerely,

Douglas A. Frei, P.E.
Chief, Planning Division

Enclosure

Salmon Decision Analysis
Lower Snake River Feasibility Study

FINAL REPORT

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Prepared for:

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October 4, 1996

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Section 1

EXECUTIVE SUMMARY

Section 1 EXECUTIVE SUMMARY

What is the Purpose of this Report?

The National Marine Fishery Service (NMFS) 1995 Biological Opinion (1995 BiOp) provides an Interim Plan to recover chinook salmon in the Snake River. It calls for increased spill and flows past the four lower Snake hydroelectric dams. The Plan directs the Corps to analyze additional measures including reservoir drawdowns and surface collectors. NMFS requested guidance on the specific design and testing of drawdowns and surface collectors.

The purpose of this report is to lay out the options for improving the hydropower system to help save salmon. There are only three options or paths available. Our goal is to provide biological criteria for each path, estimate how much it might help salmon, how long it will take, and how much it might cost. We will also compare hydropower improvements with other factors affecting recovery. Along with surface collectors and drawdowns, we identify 15 major actions (tools) that can be implemented for salmon under three different strategies we call paths, shown in Table 1-1.

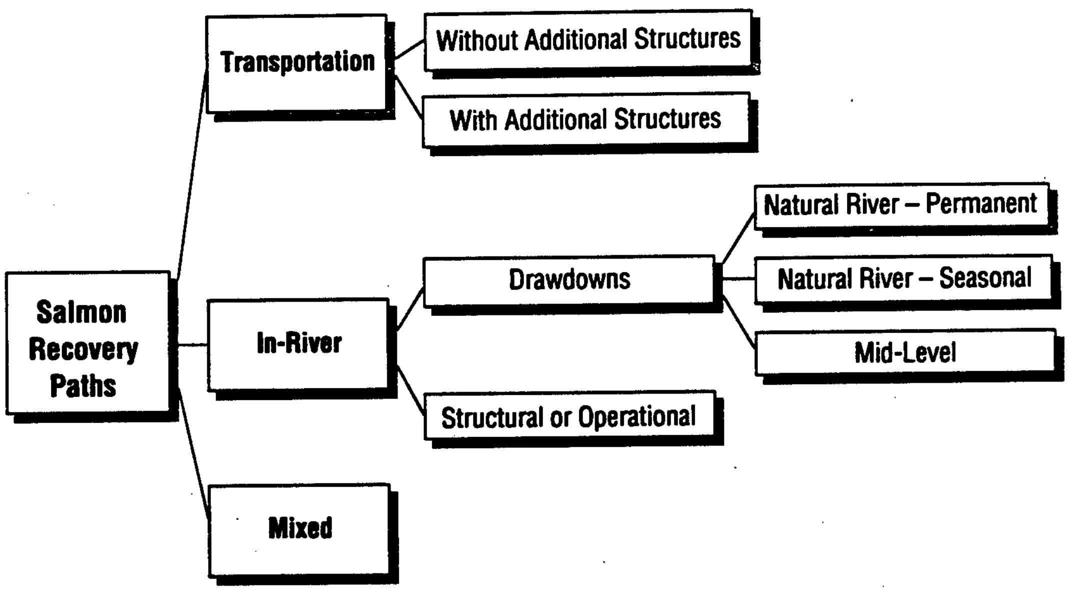
Table 1-1: Tools and Paths for Salmon Recovery

Tools	Strategies/Paths		
	In-River	Transportation	Mixed
Surface Bypasses (b), Collectors (c)	(b)	(c)	(b)(c)
Sluices	X	X	X
Baffled Spillways	X	X	X
Extended Length Screens	X	X	X
Spillways (Improve)	X		X
Turbines (Improve)	X		X
Fish Guidance Curtains	X	X	X
Juvenile Bypasses (Improve)	X	X	X
Spills	X		X
Barges/Trucks (Juveniles)		X	X
Storage (Flow)	X	X	X
Dam Removals	X		X
Reservoir Drawdowns	X		X
Minimum Operating Pools	X		X
Sound Repulsion	X	X	X

What are the Paths?

A path is a particular set of future actions that will have biological consequences in a sequential timeline. We use biological criteria to evaluate biological consequences. We envision two major paths for salmon through the hydropower system: a *Transportation Path* and an *In-River Path*. A third, *Mixed Path*, would combine both *Transportation* and *In-River*. There are sub-paths within each path. Sub-paths define more specific actions and tools within each major path (Figure 1-1).

Figure 1-1: Lower Snake River System Paths



With 15 options (tools) at four dams, too many complex combinations exist, and some combinations don't make sense. For this reason, we employ a two-step analytical method: (1) biological analysis first, and (2) decision analysis second.

Specifically, the report first develops biological or fish survival criteria for each path. After biological analysis, the options or tools are further evaluated in terms of benefits, costs, and risks. Cost is analyzed because some options require annual federal expenditures of $300 million for the next 100 years. This is equivalent to about 18 percent annual net benefits of the electricity produced at the eight federal dams. The Northwest Power Planning Council estimates that since 1982 the regional Fish and Wildlife Program has re-

duced the firm energy generating capability of the hydro system by 1,200 aMW, a ten percent loss system-wide. Risk is analyzed because there is the possibility that with even larger expenditures, target stocks could still go extinct because of factors other than hydropower impacts.

This report relies on biological data and biological risks to evaluate path options first. When traditional economic analysis is intertwined with biology, those options that take the longest to implement often produce "cost savings" over those options that can be implemented quickly. This is because the cost of lost hydropower, navigation, and recreation benefits are put off until a future date. In other words, each year the problem goes unsolved, the cheaper the problem is to fix. This makes no sense if the goal is to reduce the risk of extinction. This is why biology must be separated from economics, and why risk must be part of the decision criteria.

How are Major Paths Selected?

To select a major path, two questions must be answered. The first is, "Do juveniles belong in the river or barges?" The answer to this question is determined by comparing the smolt-to-adult return rate (SAR) of each path. If one path consistently returns 30 percent more adults than the other, then it becomes the path of choice. The 30 percent criteria is based on the assumption that this is the maximum improvement possible in In-river survival with the dams in place. If the difference in the SARs between paths is less than 30 percent, or varies year-to-year, a mixed strategy using both paths is selected (Figure 1-2). The difference in the SARs between test groups is expressed as a ratio called a TIR. The TIR is calculated by dividing the SAR for transported fish versus an in-river control group. The TIR is used to quantify transport survival which in turn is used as justification for selecting or rejecting a path (Figures 1-2 and 1-3).

The second question that must be answered is, "Regardless of how much better one path may be compared to the other, does it return enough adult salmon to reverse population declines?" We establish a minimum SAR of 1.5 percent for wild spring/summer chinook upon which all paths are compared (Section 7). This criterion is displayed on the flow chart in Figure 1-2 and vertical axis of Figure 1-3.

The SAR values established for path selection are considered threshold values at which the need for more drastic actions need to be considered. As SARs fall below the 1.5 percent criterion our willingness to consider paths with more risks, uncertainties, costs, and shorter implementation times should increase if saving Snake River salmon is the goal.

Figure 1-2: Decision 1999 - Path Selection Flow Chart

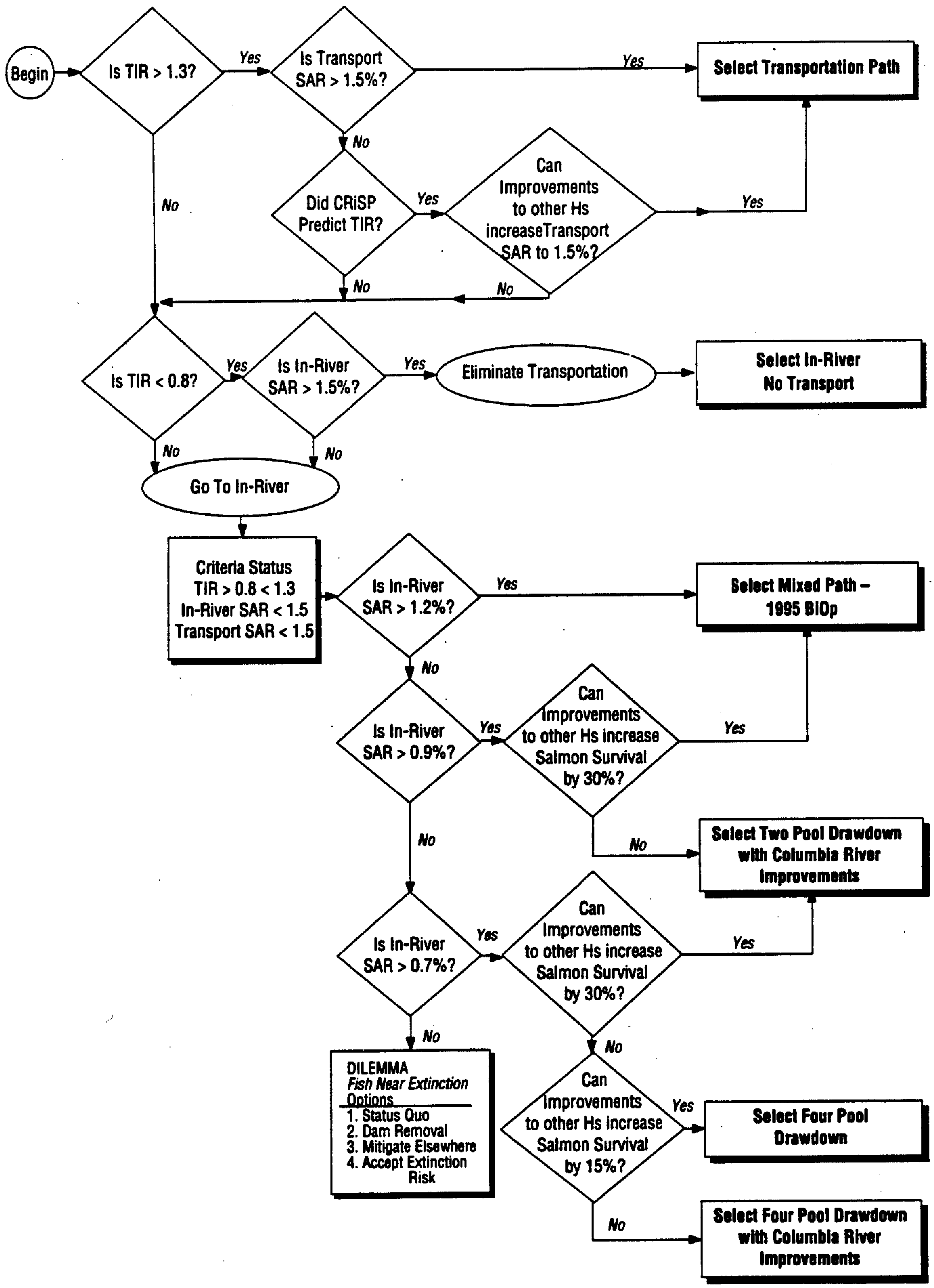
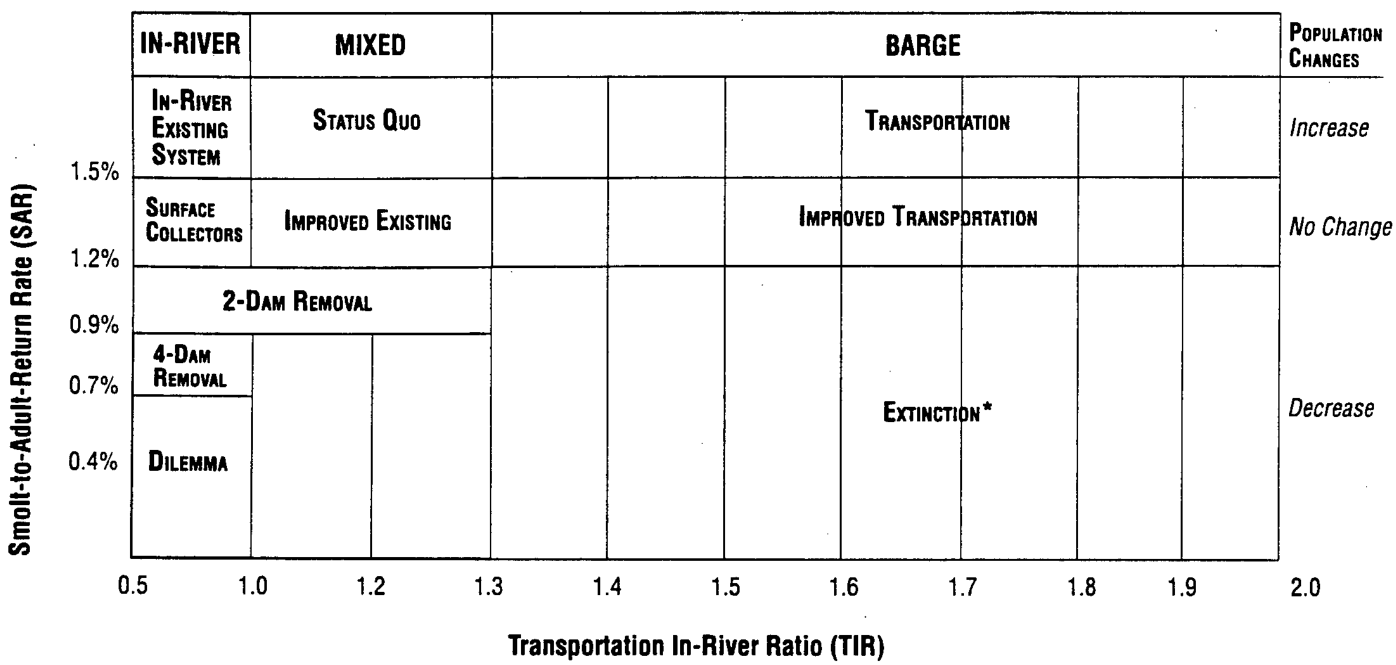


Figure 1-3: Juvenile Migration Strategy



* Assumes extinction occurs unless adult return rate increases from outside hydropower system.

How are Drawdown Sub-Paths Selected?

Assuming that *In-River* is either the selected path or part of the path (i.e., *Mixed Path*), there are up to 14 tools (Table 1-1) that could be used to increase survival and meet the 1.5 percent adult return rate. All tools that increase in-river survival are candidates. These are selected by cost-effectiveness analysis (Section 8). We have determined that the maximum increase in juvenile survival technically feasible with the dams in place is about three percent per dam (Section 5). This would increase juvenile in-river system survival from the head of the Lower Granite reservoir to Bonneville tailwater from today's estimate of 43 percent to about 56 percent. This is a 30 percent increase in salmon survival. It is assumed that a 30 percent increase in juvenile survival equates to a 30 percent increase in SAR, on average. Thus, if the SAR is about 1.2 percent then dam modifications can increase survival sufficiently to meet the 1.5 percent SAR criterion.

As the SAR drops below 1.2 percent the survival improvements realized from system modifications with the dams in place will be insufficient to achieve 1.5 percent SAR. To make up the difference will either require help from the other Hs (Habitat, Harvest etc.) or by project removal. By removing two Snake River dams and improving lower Columbia River dams, we can achieve about a 60 percent improvement in salmon survival. Thus, if SARs range from 0.9 to 1.2 percent, a two-dam removal will be needed to meet path SAR selection criteria.

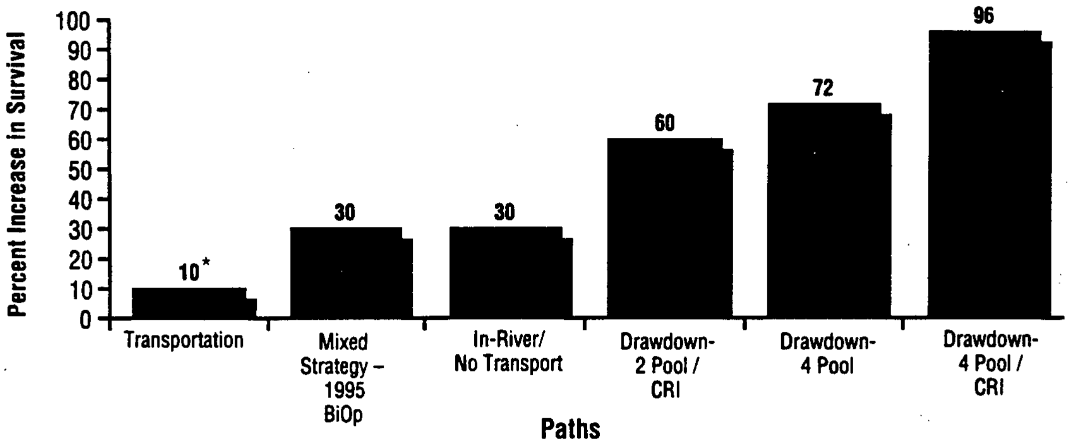
If we are 60 percent or more below our 1.5 percent adult return rate, i.e., an adult return rate of about 0.7 to 0.9 percent, we will need to remove all four Snake River dams if the 1.5 percent SAR criterion is to be met. No other changes in the hydropower system can achieve this level of survival improvement.

If the adult return rate is considerably below 0.7 percent, we have a dilemma. Simply put, survival cannot be improved sufficiently in the hydropower system to restore a 1.5 percent adult return rate even with the removal of all four dams. Improvements in survival must then come from other sources in addition to hydro improvements. The paths, and possible overall increase in survival above the existing condition, are presented in Figure 1-4.

How are In-River Tools Selected?

If adult returns are between 1.2 and 1.5 percent, tools which increase fish passage and survival with the dams in place can be used. We utilize a cost efficiency approach or tradeoff analysis to select which tool to use. Tool goals include achieving 80 percent FPE and

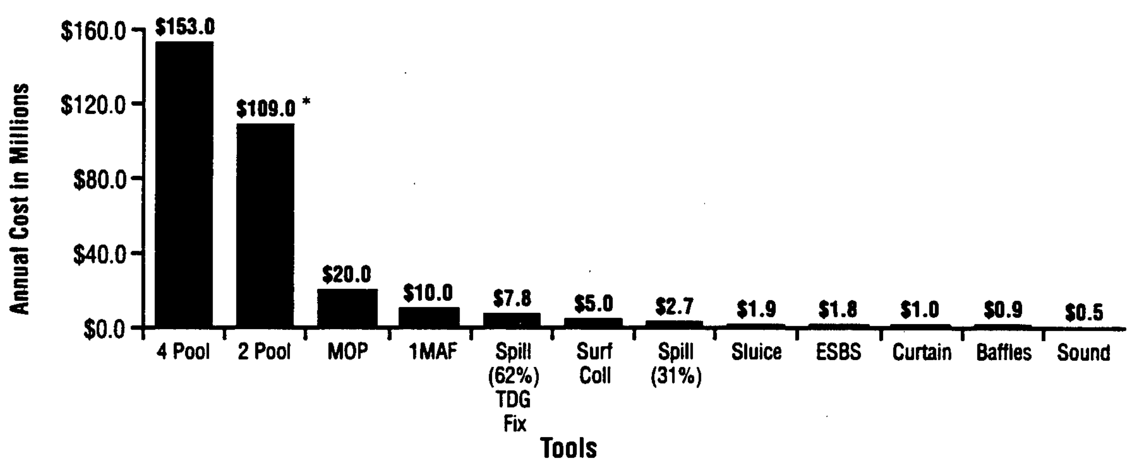
Figure 1-4: Estimated Increase in Salmon Survival for Selected Hydro System Operations (Paths)



* Depending on transport survival (50 percent or 80 percent), overall juvenile survival increases to 55 percent or 88 percent, respectively.

95 percent juvenile survival at each project as set by the NMFS BiOp (1995). The lowest cost tool to achieve these goals is the tool of choice. Tools must be proven with research, monitoring, and evaluation. The tools from the highest cost to the lowest are presented in (Figure 1-5).

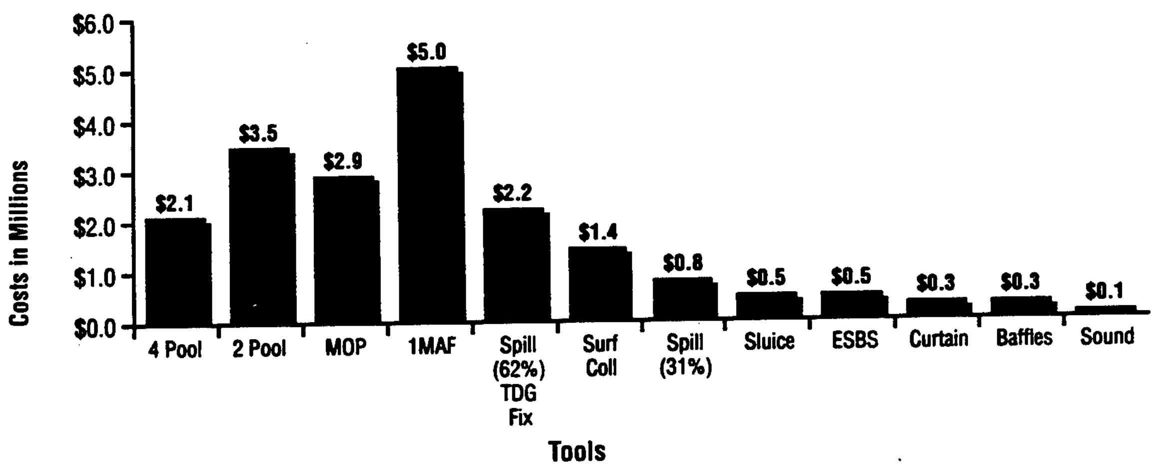
Figure 1-5: Average Annual Equivalent Cost of Selected Hydro System Improvement Tools



* Estimated; actual cost is lower as power costs are for a four-pool removal scenario.

Information as to the biological effectiveness of each tool in comparison to dollars spent are shown graphically in Figure 1-6 and discussed in Sections 7 and 8. This information is useful for recognizing tools that provide limited or reduced survival benefits. For example, it appears the tools of MOP and flow augmentation (MAF) are providing limited survival benefits at high cost while a tool such as spill (31 percent) is providing large benefits at a low cost.

Figure 1-6: Average Annual Equivalent Cost for Each One Percent Gain in Salmon Survival for Selected Hydro System Improvement Tools



Can't We Improve Salmon Survival Outside the Hydropower System?

This report focuses on criteria and choices for the hydropower system in response to the NMFS 1995 BiOp. Section 3 reviews other non-hydropower impacts to salmon. Key points are:

- The ocean has potential to overwhelm changes in the hydropower system. However, no controls exist to change ocean productivity. One economically attractive option is to do nothing at the dams and simply hope the ocean will solve the salmon problem. This has attendant uncertainties for salmon.

- Freshwater habitat degradation also diminishes salmon survival. Experts agree that freshwater habitat restoration will take decades and have unpredictable results. They also point out that dams, reservoirs, and storage are a major source of salmon habitat degradation. Habitat restoration forums are underway in all three states.

- Harvest levels of Snake River spring/summer chinook are probably less than ten percent. Fall chinook are harvested in mixed stock ocean fisheries. All harvest should be halted as soon as possible until NMFS recovery targets are reached.

- Hatchery fish are suspected of negatively impacting wild fish. Evidence on the exact nature of the problem, much less its solution, will not be forthcoming by 1999.

Habitat, harvest, and hatcheries are clearly part of the Snake River salmon problem. It seems unlikely, however, that human modification of these other Hs will significantly improve survival of wild Snake River salmon with any certainty by 1999 compared to hydropower changes.

Why is Permanent Natural River Preferred Over Other Drawdowns?

Permanent natural river has several benefits: (1) it maximizes the *In-River Path* — all Snake River hydropower impacts are removed; (2) it provides the maximum survival benefit; (3) it is simplest to design and construct; (4) it restores a truly "natural" river, including new spawning and rearing habitat; (5) it can be accomplished in about five years; and (6) it is ten times less costly and three times faster to construct than seasonal drawdown. Because of the loss of benefits from hydropower, navigation and recreation, this option has the highest economic cost.

Spillway crest drawdowns are undesirable because: (1) they retain reservoirs; (2) they retain dams; and (3) only the scale of the problem is reduced with no guarantee of comparable fish benefits. Their main attraction is that they cost less than other drawdowns.

Seasonal full pool drawdowns are undesirable because: (1) the engineering is complex; (2) construction is costly; (3) construction period is long (15 years); (4) there is nothing natural about a river that fluctuates 100 feet vertically — this will only create more biological damage in order to generate electricity for about five months; (5) it does little for adults; (6) it restores no habitat or production, in fact, it probably does more damage than stable reservoirs; and (7) its principal attraction over permanent removal is cost. Seasonal drawdowns cost about 17 percent less because hydropower generation and recreation are still possible at reduced levels.

The Detailed Fish Operating Plan (BPA, 1995), a partial seasonal drawdown with high flows, is more expensive than dam removal so it makes no sense at all. The details of this plan are in Section 5.

The current MOP operations at the Lower Snake River projects do not produce measurable biological benefits, nor are the measures cost-effective. The MOP operations should be eliminated from implementation under the BiOp and current funding requirements redirected toward other measures for salmon recovery.

In summary, the most effective drawdown measure to increase fish survival, for in-river conditions, would be a four-pool, natural river drawdown. This alternative would increase salmon survival by about 72 percent relative to existing conditions. Partial and seasonal drawdowns produce fewer survival benefits, create other biological problems, and are less cost-effective.

Can Drawdown Costs be Reduced?

One means of reducing the cost of Permanent Natural River about in-half would be to decide early (1996) and plan for dam removal in stages (begin two by 2004; complete four by 2010). Money from expenditures of studying the dams and changing the dams could be applied to reducing the cost of dam removal further. The eight to twelve year planning period would allow navigation and recreation as well as electric power industries to begin developing alternatives in an orderly process. This will increase competition to replace lost resources, further lowering costs. By anticipating this action in 1996, costs for many other expenditures could be applied to dam removal plans. For example, cost savings would accrue from:

1) The elimination of R&D studies for surface collectors, baffles, sound repulsion, fish ladders, fish curtains, temperature models, and many other projects.

2) Inefficient tools such as MOP and flow augmentation could also be eliminated and the savings credited toward dam removal.

3) Costs associated with the need for planning, design, and rehabilitation of the four Snake River dams, roughly $100 to $150 million, scheduled to begin about year 2000 could also be eliminated.

By planning ahead, the annual cost for dam removal would be about $75 million annually. In short, a decision in 1996 for dam removal by 2010 will reduce the economic and socio-

logical impacts by as much as 50 percent compared to a more sudden 1999 decision that continues to carry all paths. The hydropower, recreation, and navigation benefits must still be traded for this option. Details are in Section 8.

What are the Pros and Cons of Choosing each Path in 1996 vs. 1999?

Transportation. Returning to 1993 operations could reduce 1995 annual costs by $200 million as opposed to increasing them by as much as $153 million with other options. These cost savings could then be used to restore anadromous salmon runs in river basins throughout the Northwest. Path selection would be based on past data showing that transported fish produce *twice* as many adults as the current in-river strategy. The risk with this approach is that historical study protocols may have provided an inaccurate estimate of transportation benefits. Current data collection is aimed at reevaluating transportation benefits.

Mixed Path. This is the path defined by the 1995 BiOp that we are now in the process of implementing. Unless regional leaders direct differently, this is the path we will continue on until at least 1999 or until data demonstrate one major path is better than another. The benefits for now and until we learn differently are spreading the risk between the transportation and in-river paths. The costs include accepting large expenditures for spill, flow, and a complex R&D program with uncertain results.

In-River Path. The selection of this path would require abandonment of transportation and continuation of the development of juvenile bypass. We see little benefit of selecting this path as it accepts risks that in-river will exceed transportation benefits in a system designed for transportation. It will take ten years to re-engineer the system. The maximum benefits to fish are about 30 percent above existing in-river survival. By waiting until 1999, data will more clearly define if the *In-River Path* is superior. Costs and schedules to meet targeted improvements are uncertain since these are tied to unproven technologies.

Drawdown. As noted in the previous question the primary benefit associated with choosing a path in 1996 versus 1999 is reduced cost. With the passing of each juvenile migration season more and more changes are made at the projects to improve salmon survival. In 1996, extended length screens were installed at Lower Granite Dam. In 1997, these same type of screens will be installed at Little Goose and flip lips will be built at Ice Harbor. From 1996 through 1999 the Corps will spend significant monies building and testing surface collectors at Snake River projects. Soon the Corps will begin rehabilita-

tion plans. Such expenditures may be wasted if a drawdown path is chosen in 1999 or beyond.

Using the next three years to collect more data and test more hardware to select a path provides more information. We are uncertain whether the three years will add measurably to the existing database or influence the final decision given the discord among regional interests. There is no doubt it will add significantly to the overall cost. The Corps estimates it will expend an additional $600 million in the next 6 years. A portion of this investment would be a loss if either the transportation or dam removal path is selected.

How Does Cost-Effectiveness/Risk Analysis Affect the Path Decision?

The decision path process can be analyzed directly from the perspective of cost-effectiveness and risk analysis. Cost-effectiveness analysis focuses on reviewing measure performance per dollar spent, in comparing multiple measures. Risk analysis includes the application of sensitivity analyses, where the effectiveness of measure variables are varied. When coupled together, cost-effectiveness and risk analyses can bring into perspective the range of measure effectiveness and clarify the economic trade-offs.

For major paths, cost, benefits, and risks are summarized in Figure 1-7. This table illustrates the importance of sensitivity analyses used to compare transportation with in-river fish passage survival TIRs. When TIRs are varied, dramatically different conclusions are obtained about the effectiveness of transportation versus river drawdowns. For example, if the transportation TIRs calculated for the 1994-1995 outmigration are consistent with past observations—TIRs greater than 1.8—then the transportation path would exceed all other possible measures, including natural river drawdowns. Inversely if the TIRs are low (about 1.0), then the drawdowns would be the most cost/risk effective choice to save salmon. It also is apparent that the transportation path could be significantly more cost-effective than the other path alternatives. Reservoir drawdowns would likely offer a moderate-to-high level of biological effectiveness but do so at relatively high cost.

A Decision (Tree) Analysis was attempted. The analysis lays out the cost, benefit, risk, and uncertainty of virtually every possible combination (hundreds) of choices (tool combinations). It identifies those options with the highest benefits, and least cost or risk. Although we have cost information, these analyses could not identify any clear "best options" because they require precise quantitative knowledge about biological benefits and risks of each option. Many tools are not adequately tested to adjudge biological benefits and risks. Even with future testing, the stochastic nature of salmon populations and our

Figure 1-7: Path Benefits, Risks, and Costs

Path/Sub-Path	Time to Execute	Potential Benefit	Uncertainties	Other Benefits or Costs
Transportation	Zero	5-10% per dam juvenile survival (50-80% juvenile arrive alive at estuary). High sensitivity.	May be inadequate to recover wild fish given status quo of other three Hs.	Lowest $ cost path. Save $200 million annually. Low socio-economic impact.
Permanent Drawdown	Three years — Five years	10% increased survival of juveniles and 3% adults per dam up to four dams. However must incur in-river uncertainty at four Columbia dams and vagaries of low ocean productivity.	Takes five years to remove all four dams. Stocks could go extinct in the interval or later due to other Hs.	Highest cost path. High ecological benefit. More fall chinook spawning possible. Provides adult benefits. Irrevocable decision. Cost additional $150 million annually.
Mid level and Seasonal Drawdown	Three years – Sixteen years	If travel time is key, could help improve adult net rate; amount totally unknown. 0-5% per dam maximum benefit.	Engineering is complex and costly. Higher fish passage mortality possible. Migration speed may not help recruit more fish.	Highest construction cost. Longest construction time. Low economic benefit. High social impact. High ecological impacts. Cost up to $130 million annually.
In-River Improvements with Dams: Surface Collector, etc.	Ten years	3% improved juvenile survival per dam possible. However, must incur in-river mortality at four lower Columbia dams.	Time risks similar to dam removal. Benefits less than embankment removal. May not meet FPE goals.	Cost depends on technical solution. High construction cost. Moderate-Low O&M cost. Lower social impact. could cost $10 million annually for Snake River projects.
Spill/Flow NMFS BIOP	Zero – Ten years	80% FPE / 95% survival. 3% juvenile improvement per dam.	Unknown FPE/unknown gas; fish incur in-river risks at four Columbia River dams.	High energy costs. $125 million annual cost above 1992-1993 operations. Gas mitigation would add $10 million annually. Use of baffles could save $127 million annually if successful.

limited ability to measure subtle differences among options in an "uncontrolled" environment, limit the value of Decision Analysis. The one area Decision Analysis shows promise is in comparison within thirty-six Transportation options. Here, there are rapidly diminishing benefits with each new facility constructed.

What are the Annual Costs of Each Tool?

The following table is a synopsis of projected annual costs for each tool if applied to Snake River dams. Costs expended do not provide equivalent fish benefits. Note that the first three tools, Transportation, Baffles, and Sluices, could actually reduce costs from 1995 baseline (BiOp). Baffles should have high research priority due to potential cost effectiveness for the *In-River Path.*

Table 1-2: Annual Equivalent Cost of Tools

Tools	Annual Costs (rounded to $1 million)
1. Transportation	($200 million)*
2. Baffled Spillways (4)	($10 million)
3. Sluices (4)	($6 million)
4. Sound Repulsion	$1 million
5. Fish Guidance Curtain	$1 million
6. Juvenile Bypass Fix	$1 million
7. Extended Screens (2)	$4 million
8. Surface Collectors (4)	$9 million
9. Minimum Operating Pools	$20 million
10. Permanent Drawdown (4)	$153 million

* 1995 BiOp is base case. The spill/flow program costs $125 million above 1992-1993 operations plus R&D costs.

What Research Issues Need Resolution if We Wait Until 1999?

The major issue needing resolution in 1999 is the quantification of the survival rate for transported juveniles. If transport survival is high (80 percent) then none of the other paths, including four-dam removal, increases juvenile survival above the rate possible with transportation. If transport survival is low (50 percent) then all of the in-river paths can match or exceed this level. The cost differential between the *Transportation Path* and the *Four-Pool Drawdown Path* is approximately $350 million annually. Other research issues needing to be addressed include adult homing, handling, and delayed mortality effect of

JBS systems on SAR. To ensure that monitoring and evaluation are adequate, the region should: 1) continue to install PIT-tag detectors at projects and conduct reservoir-project passage survival studies; 2) employ additional methods to verify the transportation TIR and SAR values prior to 1999, including new experiments that contrast upper river versus lower river survival; and 3) rely on available data and statistical methods to estimate the effects of ocean conditions on Snake River salmon survival relative to in-river conditions. All of these issues are discussed in more detail in Section 11.

What are the Twelve Key Points of this Report?

The report addresses the comparative merits of various hydro system changes aimed at restoring wild spring/summer chinook populations to non-threatened status in the Snake River basin. The most significant aspects of the report are summarized in the following twelve itemized paragraphs.

1. The report recommends the elimination of further study of seasonal and or partial drawdowns. Permanent dam removal is the only "drawdown" option that is worthy of further study. Compared to other drawdowns, it maximizes biological benefits and minimizes construction costs and schedules. Although permanent dam removal costs $23 million annually more than seasonal drawdowns due to lost hydropower and recreation benefits, the cost differences are small (about 7 percent of the range of cost alternatives) and the biological differences big. Partial drawdowns offer limited and uncertain biological benefits to fish that can be equalled by other, lest costly, less risky, in-river tools.

2. All options for change in the hydropower system are characterized in three paths:

   (1) Transportation of juveniles in barges,

   (2) Modification to dams to improve in-river migration,

   (3) Mixed approach using both (1) and (2).

3. Fifteen "tools" or options are currently under evaluation throughout the region to utilize as is, or to make the hydro system more fish friendly. The least costly is to use existing transportation and return to pre-fish flow operations (hydropower load following). The most costly is to remove all four Snake River dams. A complex of choices between these two extremes is also identified. They use both transportation and in-river strategies. Each tool or option has an identified cost and fish survival improvement goal.

4. Selection among the options involves both value judgments and trade-offs. Quite simply, dam removal is the biological option of choice if salmon and *ecosystem restoration* is the primary goal. Removal of four Snake River dams will increase salmon survival by about 72 percent above existing in-river levels. Dam removal plus improvements to lower Columbia River dams included would about double annual salmon population production. No other in-river option can match this biological benefit or the speed of implementation (five years).

5. Because transportation removes juvenile fish from the river, a separate comparison is needed with in-river options and benefits. The first comparison is how many adults return from transported juveniles versus from those migrating in-river. If the SARs of the paths are within 30 percent of each other, we recommend utilization of both. This is the *Mixed Path*. If transportation achieves adult returns of 1.5 percent and exceeds in-river migrants by more than 30 percent, it should be selected exclusively. In this case, trade-off analysis is used to evaluate benefits of higher collection efficiency. Transportation benefits can be improved about 10 percent by increasing FGE and improving handling methods. At greater issue is the level of delayed mortality on transported fish. Elimination of Minimum Operating Pools at all Snake River dams are also recommended in this path as they cost $20 million annually and provide no measurable benefit.

6. Comparison of the other 13 options or tools is a trade-off analysis. What is "traded" is the increased survival of juvenile fish in-river and resultant (expected) adult returns for the cost of each tool. Since many of the tools are unproved, there are associated risks and uncertainties as well as costs. These are described in the framework of Decision Analysis. The maximum in-river improvement in salmon survival with dams is about 30 percent if technology meets targeted goals or about one-third of dam removal benefits with Columbia River improvements. Estimated schedule to reach a maximum improvement is ten years.

7. To provide comparison among all tools that improve in-river survival of juveniles with dams in place, we establish a target goal of 80 percent fish passage efficiency (FPE) and 95 percent per project (concrete) survival. These goals were set in NMFS 1995 Biological Opinion. The least cost tool that can meet or come closest to this goal is the in-river tool of choice. Since spill is NMFS primary and existing tool of choice (no construction required), all tools are compared to spill for both cost and effectiveness. The least cost tools are spillway baffles and sound repulsion, followed by fish guidance curtain, extended turbine screens, and ice/trash sluice bypass. All cost less than spill ($2.7 million per project annually), if they can meet technical criteria.

Costing more than spill for equivalent fish benefits are surface collectors, storage (1 MAF costs about four times more than spill) and Minimum Operating Pools (MOP at four projects costs about eight times more than spill). (Similar comparisons are valid for John Day but are not analyzed here.) Four dam removal is about twice as cost effective as MOP and Storage (1 MAF). But spill and other less costly options are more than twice as effective as dam removal (twice as many fish pass the dam per dollar invested). None of the "with dams" options can achieve the same maximum amount of increased survival as dam removal; they take longer to implement and they have more risks and uncertainties. The simplest way to put this is that there is a point of diminishing fish benefits that can be achieved with the dams in place. The report estimates that the maximum improvement theoretically possible is to improve the existing project (including reservoir) survival of about 90 percent to about 93 percent. This assumes the new bypass technologies with dams in place are effective.

8. Because it is possible that neither transportation nor in-river improvements with dams in place may return sufficient numbers of wild adults (i.e., both may lead to extinction), a criterion is established for how much improvement is required to avoid extinction. Based on the best available data and professional judgment, we establish an adult return rate for wild fish of 1.5 percent as the dividing line between population increase and decrease. Historic populations of Snake River salmon returned at rates greater than two percent, so 1.5 percent is conservative. If return rates continue at levels below one percent with the existing system and recent ocean conditions, it will not be possible to recover Snake River salmon using transportation or with the dams in place. Only dam removal will provide sufficient benefits to have any chance for reversing decline. The potential to increase adult return rates outside the hydropower system exists by improving freshwater habitat, or by hoping ocean productivity will improve. The ocean is uncontrollable but can have more influence on population changes than changes at the dams. Experts on freshwater habitat suggest improvement may take decades and there are no reliable ways to estimate survival from habitat improvements that will occur in the next ten years. Goals are being set in other forums.
9. If adult return rates are less than 0.7 percent, even dam removal will not provide sufficient improvements to push survival above 1.5 percent. Hydropower improvements can only about double the return rate as regulated by all other non-hydropower factors.

10. The report provides a rationale for selecting and rejecting each of the paths. It provides a rationale for making a path decision in 1996 or collecting more data to evaluate and select a path in 1999. It provides examples of the data that are being collected

or could be collected to adjudge each tool and each path. It also provides estimated annual costs for each path and each tool. These range from reducing existing costs by $200 million annually (*Transportation* only, no *In-River Path*) to increasing existing annual costs by $153 million (four dam removal).

11. The report recognizes that the Snake River dams are scheduled for rehabilitation and upgrading beginning about the year 2000. Costs could range from $100 to $150 million. Much of this cost can be avoided if the dam removal decision is exercised. Rehab costs can be redirected to other system requirements as appropriate. Likewise, if the dam removal option is eliminated, rehabilitation plans can be made with more efficiency and certainty. It makes little sense to proceed with costly dam investments for fish or power if dam removal remains a viable option for recovery. Maintaining all options for long periods of time drives costs and risks upward.

12. One noteworthy economic consideration concerns timing of dam removal. If the Dam Removal Path were to be selected in 1996 and slated for implementation by the year 2010, it would reduce the annual equivalent cost of a Natural River by roughly half or a $75 million annual cost because the economic impacts are delayed. These savings will be refined with further analysis. However, regardless of timing, the loss of hydropower, navigation benefits, etc., will be of the same order of magnitude. The System Operation Review is used as a basis for comparison of this and all other path costs.

In conclusion, this report attempts to summarize and synthesize what we know about science, engineering and economics. The data cannot predict future ocean conditions. They cannot equate an "ecosystem" with a "hydro system." They cannot eliminate all risks and uncertainties.

Although availing ourselves to as much data as possible is a wise and prudent path in itself, sooner or later choices will come down to value judgments about our knowledge, about risks, about costs, and about ecosystems and hydro systems.

Section 2

DEFINITION OF THE PROBLEM

Section 2 DEFINITION OF THE PROBLEM

The Corps of Engineers Walla Walla District is studying and designing various improvements for the passage of salmon across the four Lower Snake River dams. Their activities respond to specific items within the National Marine Fishery Service's (NMFS) Biological Opinion and draft Recovery Plan and the Northwest Power Planning Council's (NPPC) Fish and Wildlife Program Amendments. Because of the high cost, long planning times, risks and uncertainties, the Corps must eliminate certain paths and choose those that will be effective toward species recovery and non-redundant.

Table 2-1 lists the current and future options. There are two major and potentially costly new components to the Corps' SCS program. One is the investigation and design of new methods to pass juvenile fish down river via the reservoir surface instead of turbine intakes (surface bypass). The second is the use of drawdowns (lowering pools) to expedite juvenile migration to the ocean.

Table 2-1: Major Tools For Recovery

CURRENT PROGRAM	FUTURE OPTIONS
1. Transportation	1. Surface Collectors
2. Extended Length Screens	2. Drawdowns
3. Spill	3. Curtains
4. Flow Augmentation	4. Spill Baffles
5. Flip Lip Spillways	5. Dam Removals
	6. Sound Repulsion
	7. Better Turbines

Beside surface bypass and drawdown, the Corps is also designing flip lips to reduce total dissolved gas (TDG) from spill, and attempting to reduce the number of juveniles entering turbines by designing, testing and installing prototype fish guidance curtains, extended length screens, and sound repulsion systems. An advanced fish friendly turbine design is in a research and development phase.

Simultaneously, the Corps is continuing to use, improve, and test (with NMFS) transportation, the twenty-year-old method of capturing and moving fish past the dams in barges/trucks. Wild and hatchery salmon stocks in the Snake have declined despite turbine screen bypass and transport programs that began shortly after the four Lower Snake dams were completed in the mid-1970s. Spill and flow augmentation are being used as interim measures to protect in-river migrants until a final recovery plan is implemented. Neither the System Operation Review or the Recovery Plan provided criteria or tests to implement specific costly options such as drawdowns, dam removals, and surface collectors.

Path Analysis

The focus of this report is to lay out the options for improving the hydropower system to help save salmon. There are only a few options or paths available. Our goal is to provide biological criteria for each path, estimate how much it might help salmon, how long it will take, and how much it might cost. We will also compare hydropower improvements with other factors affecting recovery such as freshwater and ocean habitats, climate, and agricultural practices. We identify the need for goals and criteria for the other three Hs of Habitat, Harvest, and Hatcheries. The specific goals and criteria for the other three Hs must be addressed in other forums.

After review of all tools/options to reduce salmon mortality at the dams, we concluded there are three major paths for enhancing juvenile survival through the hydroelectric system (Table 2-2). The first is the *Transportation Path*, the second is the *In-River Path*, and the third is a *Mixed Path* using both transportation and in-river improvements.

Table 2-2: 1999 Recovery Plan

Make One of Three Path Decisions

TRANSPORTATION	MIXED	IN-RIVER
Improve:	*Combine:*	*Add:*
Collection	Best of Transportation	Surface Bypass
Handling	and	Baffle Spill
Barges	In-River	Flow Augmentation
JBS		Lower Reservoirs
No Spill		Remove Reservoires
or		Improve Turbines
Flow Augmentation		

Transportation Path. In this path, Snake River juveniles are captured via screens at one or more of the dams they encounter during their migration (Figure 2-1 and Figure 2-2).

Figure 2-1: Juvenile Salmonid Collection and Transportation System

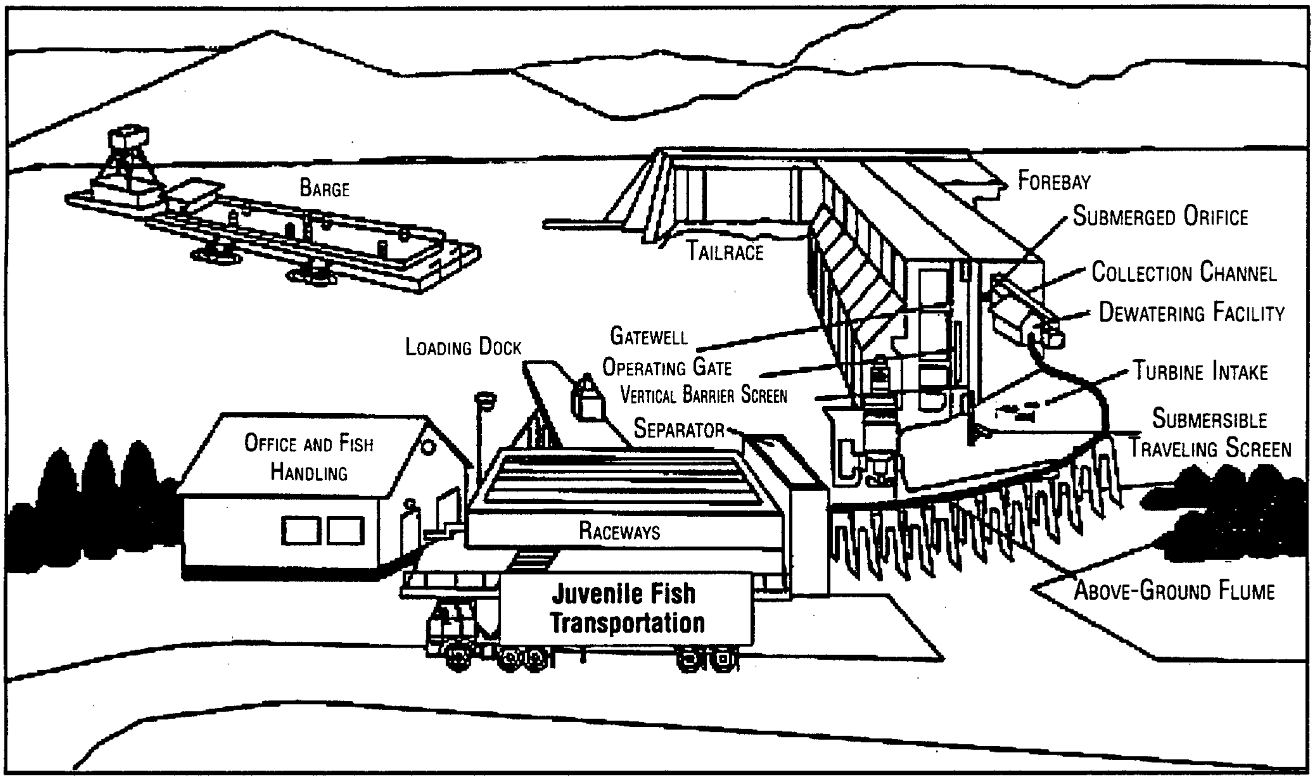


Figure 2-2: Downstream Migrant Passage Route Through Dams

via 1) turbines; 2) Juvenile Bypass System (JBS); 3) spillways; and
4) sluices for ice and trash (if present); each route has 1-10% mortality

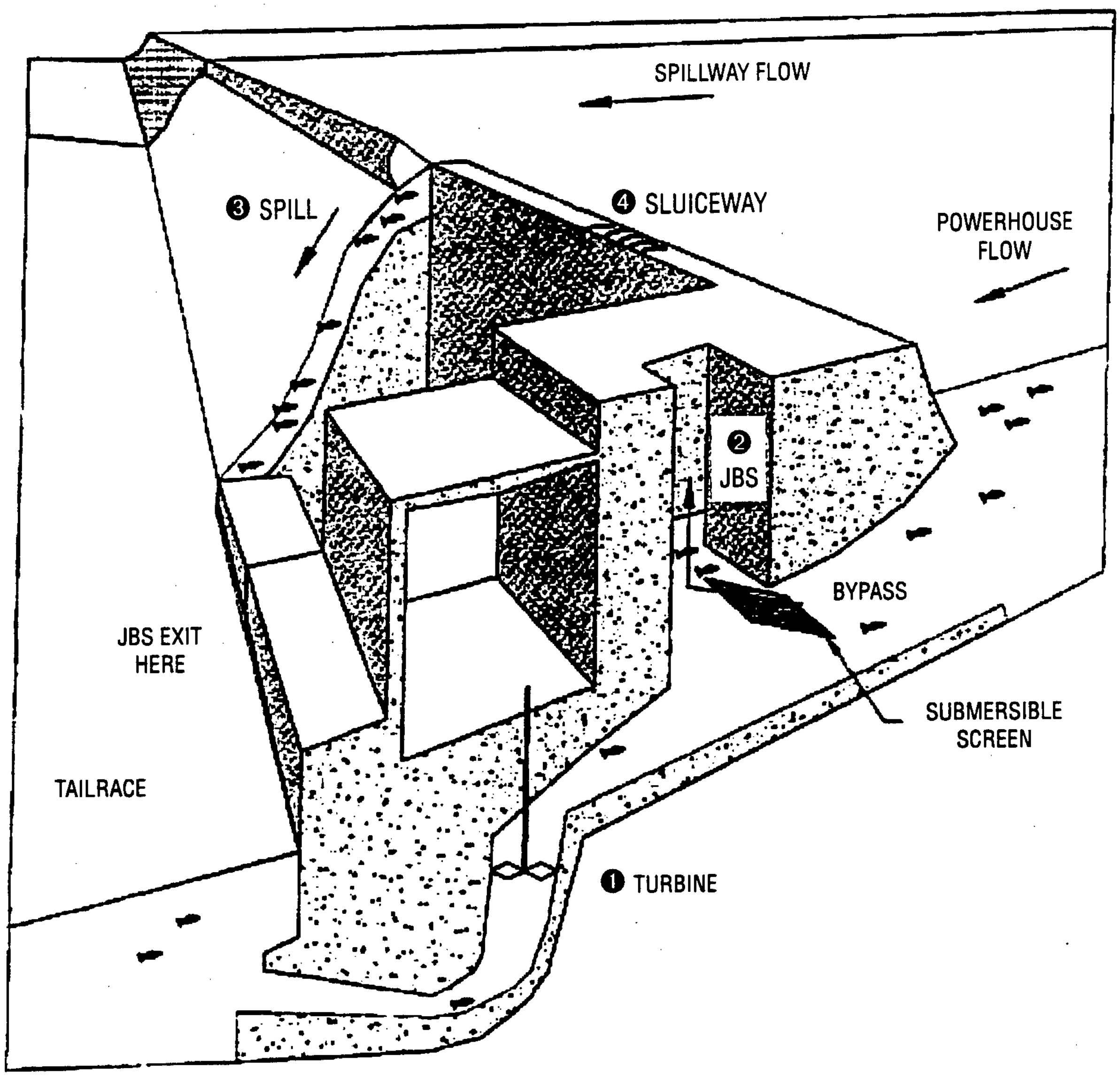
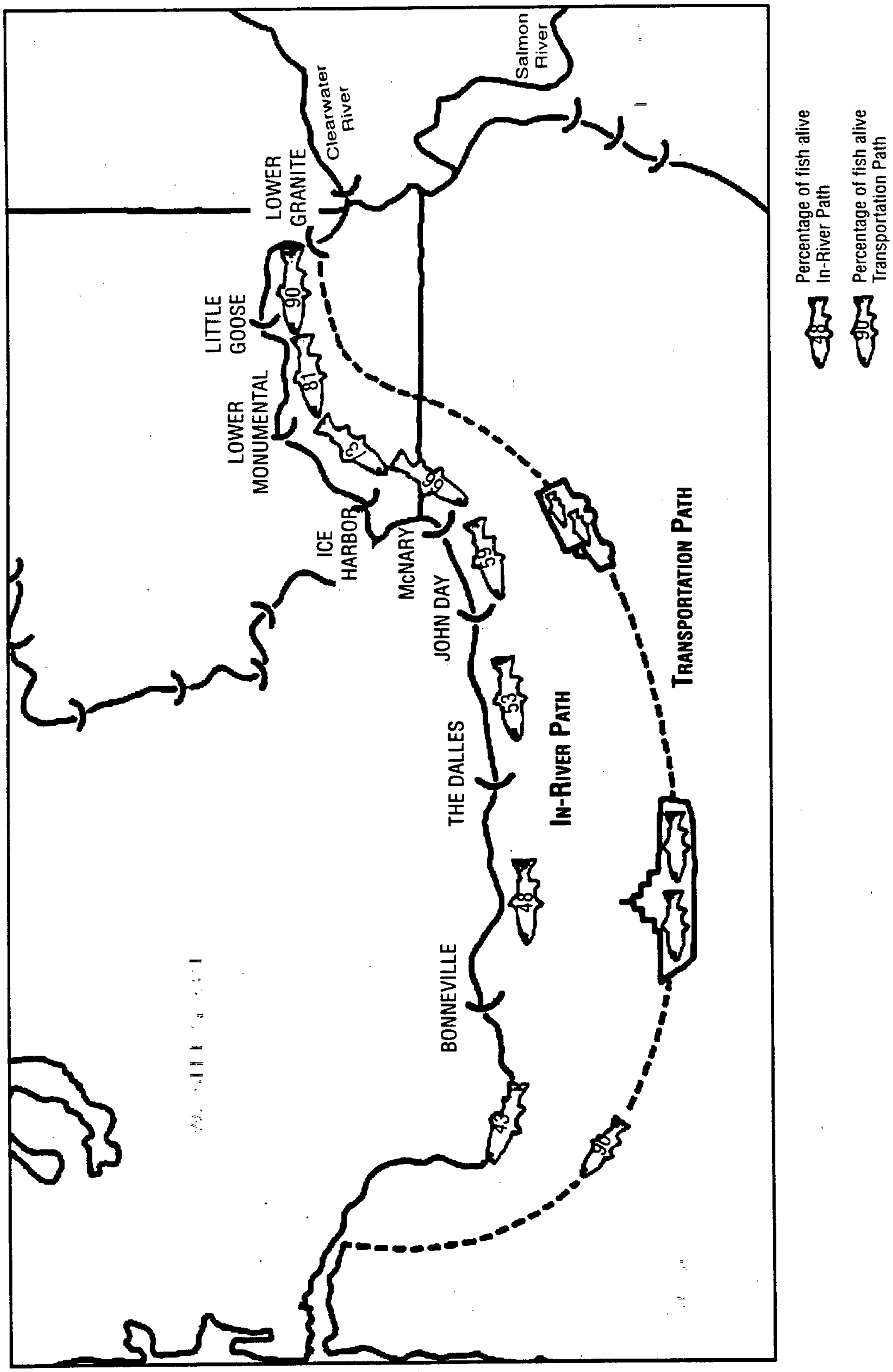


Figure 2-3: Comparison of In-River vs. Transportation Routes

with acute mortalities In-River route loses 10% per dam;
transport route loses 10% per barge trip; ratio 2:1 transport



Collection now occurs at four dams because screens capture only about half the juveniles passing each project. Anecdotal observations suggest that most juveniles transported in barges survive the two-day trip down river. Some may die later due to the stress of transportation based on CRiSP model estimates. This latent mortality and its quantification is an important issue in selecting paths.

In-River Path. Unless transported, Snake River salmon swim through eight hydroelectric facilities as described above (Figure 2-3). Juveniles that are not transported by barge pass through turbines, screens, bypass outfalls, or spillways (Figure 2-2). Each route kills between one to ten percent. Project (dam and reservoir) losses are about 10 percent of the passing migrants depending on design, operation, flow, temperature, and species. About 57 percent of the Snake River juvenile spring chinook salmon die during migration each year between the Lower Granite reservoir and Bonneville Dam tailrace (Figure 2-3). This path will require substantial changes to the dams to facilitate biologically meaningful improvement for chinook populations.

Mixed Path. A third possible path is to combine the *Transportation* and *In-River* paths into a *Mixed Path.* This path is selected as a default if: (1) tests are unable to prove either *Transportation* or *In-River* is clearly superior, or (2) tests show that superiority of the first two paths varies by year. For example, *Transportation* may return more adults in years of very high and very low flow when gas or temperature could be a problem for juveniles. The *Mixed Path* would enable a choice of using *In-River* or *Transportation* each year, either alternately or simultaneously.

All Snake River adult fish that survive the ocean and estuary can pass upstream via ladders but can be delayed or fall back through turbines. In general, adult loss is estimated at three percent per dam. Potential improvements for adults mostly involve modification of ladders or natural river drawdowns.

Because ESA mandates recovery, we use biological data as the first criterion for path selection. The path that can return the greatest number of spawning salmon is the biological path of choice. We also present a decision tree analysis for each path that combines biological benefits with other components of path selection including costs, risks, uncertainties, and schedules.

The initial task is to determine the biological benefits of each major path, *Transportation*, *In-River*, or *Mixed.* To do this, we review the existing data, set evaluation criteria, and recommend specific test data to select a major path. It will also be necessary to evaluate sub-paths. For the *In-River Path*, sub-paths will include drawdown, embankment

removals, and surface collectors. For the *Transportation Path*, sub-paths will include improved methods to capture, handle, and release fish. The *Mixed Path* will also contain these options. The sub-paths will be evaluated using biological criteria and other factors including risks, costs, and schedules.

The Current Dilemma: Which Path and How to Choose

Two basic problems have precluded universal acceptance of the *Transportation Path*. One is that if transportation is good, why are Snake River salmon stocks near extinction? The second problem is objection to the test methods used to compare the *Transportation Path* with the *In-River Path*.

Proponents of the *Transportation Path* point to habitat degradation, poor ocean conditions, drought in the basin, as contributing reasons for salmon decline, not the failure of transportation. Salmon decline in other basins corroborates that these causal elements are having effects. Proponents also note that transportation experiments to date mostly show it to return more adults. There are a few exceptional years when in-river fish equaled or bettered transported fish. Statistical comparisons are unavailable for fall chinook and sockeye out of the Snake but transportation shows benefits to Columbia River fall chinook.

Opponents of the *Transportation Path* have expressed several legitimate criticisms of the transportation experimental data and the hydropower system impacts to in-river fish. Essentially these are: (1) poor in-river conditions (no spill, low flows) for migration to make transportation look better than it is, (2) poor experimental protocols, and (3) differences between wild and hatchery fish response to transportation. They also emphasize that the *Transportation Path* currently appears insufficient to maintain or restore Snake River salmon populations. It is clear that a variety of problems are limiting recruitment in the Snake River. The ocean seems to have the largest impact, but apportionment of the impacts among a plethora of mortality sources is difficult.

In-river migration and survival can possibly be improved with a variety of tools including surface collectors, improved screens, improved spill, natural river drawdowns, and others but the net benefits are currently uncertain. The time and resources to complete prototypes and tests of all options is limited.

Delay in itself in deciding which path to choose is also a risk. Action is needed to prevent extinction.

The goals of this study are to:

1) Define the future paths open to recovery,

2) Define the tests and decision criteria needed for path selection, and

3) Provide a path analysis without selecting a specific path.

Costs, risks, and schedules are also included for each path but are treated separately from biological criteria.

Organization of the Report

Two over-arching intentions of this report are to (1) simplify the complexity of options to help salmon, and (2) to separate the science and economics of the options and make them understandable to everyone. The Executive Summary provides a description of the options and the science and economics behind each. It contains key facts and recommendations.

The basis for each fact or recommendation is contained within one of eleven sections. This allows reviewers to selectively read issues of greatest concern without reading cover to cover.

Section 3

CHANGES AFFECTING SALMON

Section 3 CHANGES AFFECTING SALMON

Salmon Trends from 1970 to 1995

Spring chinook adult returns have been compared from the Snake River to other West Coast rivers and to West Coast populations aggregately. The purpose is to see how the Snake River populations are doing compared to other populations and to the overall West Coast spring chinook population as a whole.

We re-examined data from Olsen and Richards (1994) on the salmon return rates for the Snake, the Rogue, the Fraser, and the West Coast. The data are shown in Figures 3-1 to 3-4. Using these data, Olsen postulated that the ocean is responsible for the highly correlated levels of increasing and decreasing West Coast salmon populations. Compare for example the similar shape of the population from Fraser River to the Snake River (Figure 3-5). There is now little doubt that the ocean return rate for salmon is affected by large scale and long term physical effects. These in turn have large scale and long term biologic (food chain) effects. *El Niño* is one of the major physical phenomena affecting fish populations from Peru to Alaska including salmon in the Northwest. Olsen showed that the actual rate of return of Snake spring chinook was higher in 14 of 19 recent years than other populations, yet the total Snake River spring chinook population continues to decline.

In light of this apparent contradiction, we re-examined some of the characteristics from among the Snake, the Rouge, the Fraser, and the West Coast populations. The Snake and the Rogue which are the two smallest populations fluctuate much more radically from year-to-year than the much larger Fraser or West Coast Aggregate. The Snake and Rogue fluctuated between 10-fold and 16-fold in size in the 22-year period. Cramer (1996) noted a 30-fold fluctuation in salmon stocks from the lower Columbia (Cowlitz). The Fraser and West Coast show only about a two-fold fluctuation. In terms of extinction probability, these fluctuations are far more important than long term average population levels. Smaller populations may be more prone to fluctuate and more prone to extinction.

Figure 3-1: Snake River Spring Chinook Salmon Adult Returns

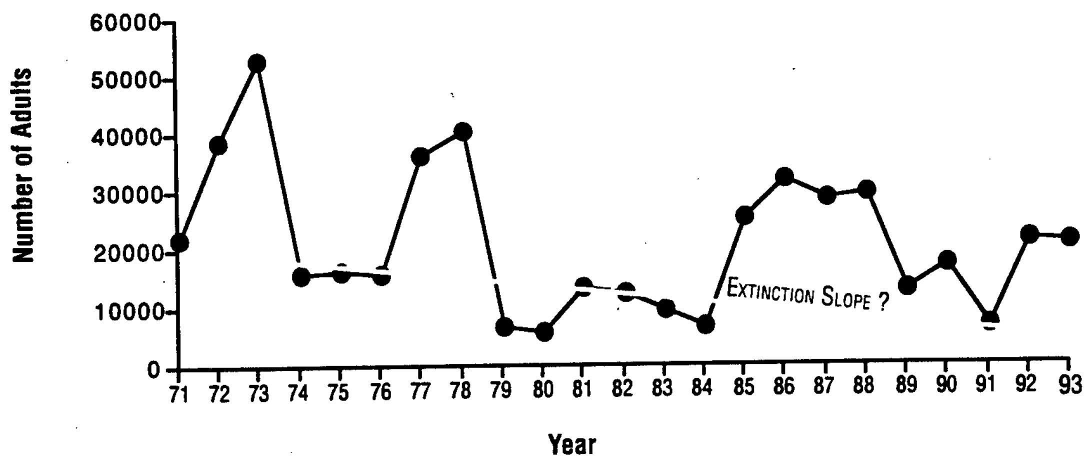
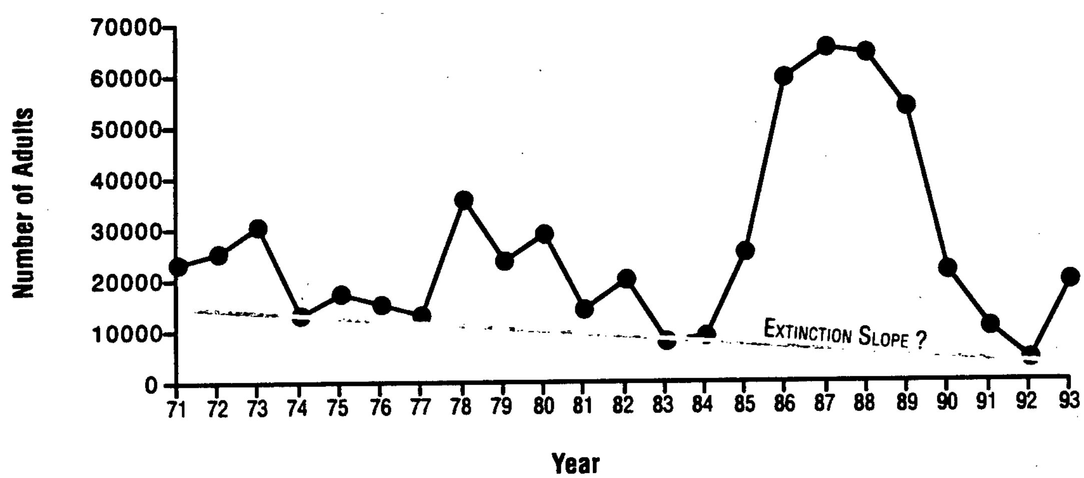


Figure 3-2: Rogue River Spring Chinook Salmon Adult Returns



As a percent of their total population size, notice how frequently and how closely the Rogue and Snake populations dip toward the zero (extinction) line. The Fraser and West Coast aggregate never approached the zero (extinction line) in the past 22 years. An eye-fit line to the low points on the population curves suggest that the population oscillations

Figure 3-3: Fraser River Spring Chinook Salmon Adult Returns

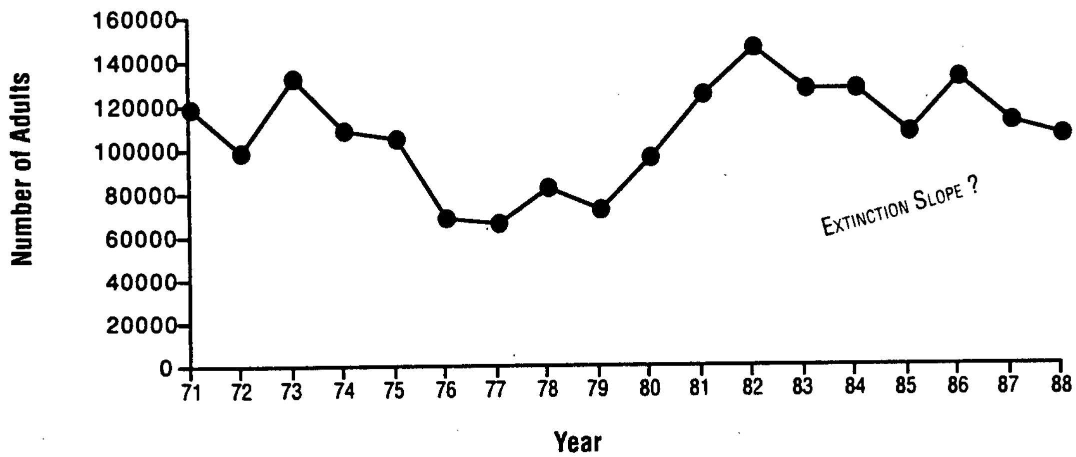
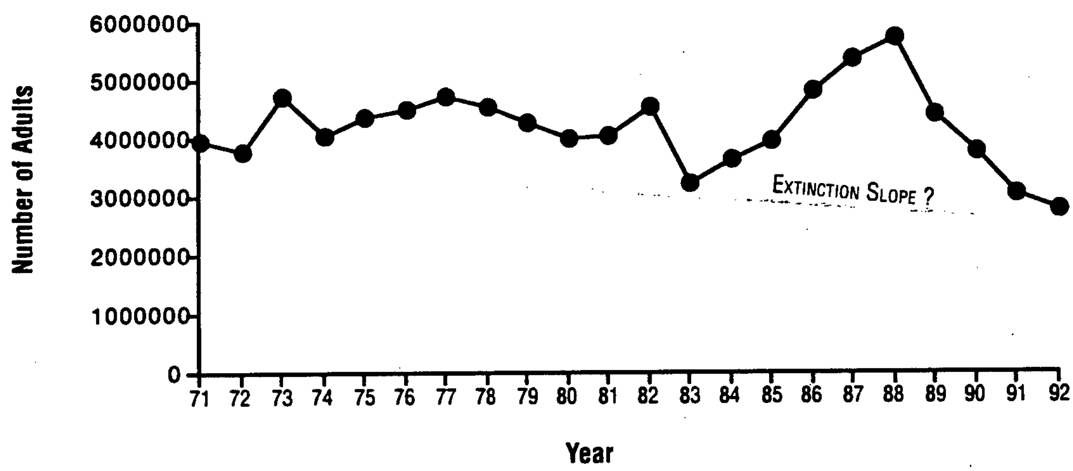
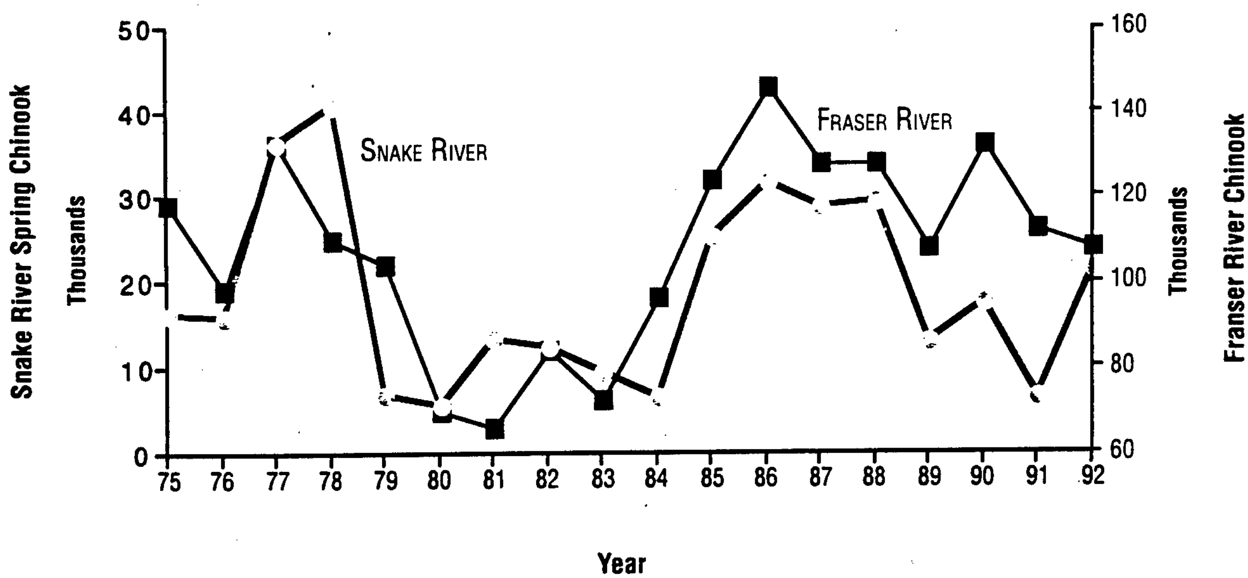


Figure 3-4: West Coast River Spring Chinook Salmon Adult Returns



are getting lower each year. Extending the Rogue and the Snake lines intercepts the zero (extinction) point in about five years. Extending the West Coast lines intercepts the zero point in about 50 years. The Fraser line does not show a distinct downward trend.

Figure 3-5: Snake River Spring Chinook Escapement vs. Fraser River Chinook Terminal Run



Although small population size is a potential factor that could expedite extinction, it is interesting that even the larger West Coast aggregate shows a declining slope albeit less steep than the Snake and the Rogue. The Fraser, an unregulated river, shows no obvious declining trend toward extinction.

There is good news and bad news in these numbers and trends. The good news is that it is possible to obtain a five-fold increase in populations of salmon in only two years (see 1984-86 in both the Snake and Rogue). If we have sequentially good ocean years, hopefully, this can redouble the capital. Salmon have great reproductive potential. The bad news is that declines (troughs) can be even more dramatic than the peaks. When specific brood years get close to zero return rate, those low returns will reoccur in rolling waves every two or three years (see 1973 to 1984 Snake River).

To understand the potential risk of extinction think of the ocean return rate as the stock market that fluctuates year to year. Some years it might increase five percent; some years 20 percent. The juveniles going out are like the capital in the investment account. If our capital gets close to zero, it doesn't matter if the growth rate is 100 percent. With little capital, we will see little growth in the account. Right now the 1991-1992 brood years for the Snake River account are nearing zero. The 1995 migration year may be the last big account.

There are several important points in these data that are relevant to the future of Snake River salmon and proposed changes to the dams.

1) Small populations are more subject to wild fluctuations than large populations. Local extinction of small populations may occur because of random impacts regardless of future actions. Small populations plus fluctuating ocean conditions inherently increase the risk of extinction of specific brood years regardless of other factors.

2) Small or depressed populations will rebuild much more slowly than large populations. As the population approaches zero, recovery is nearly impossible in any short period of time (human time scales) because all the capital reserves have been spent.

3) We spend capital (fish) whenever we withdraw (Harvest) them from our account. Think of juveniles as one dollar bills and adults as 1000 dollar bills in our account.

4) Notice that only the unregulated (Fraser) river among the four examples shows no indication of heading toward extinction.

So, what should we do, or not do, based on these observations? First, if the stock market (ocean return) does go up in the future, don't assume that we caused it by our small actions in freshwater. Instead, bank every dollar (fish) possible and assume it will be needed to withstand the next downturn. Second, as part of risk analysis and recovery planning, we should not be surprised if small sub-populations go extinct within the next five to ten years. The risk of extinction will exist for small brood years in spite of near term future actions. Third, as the population declines to a few hundred individuals, population rebuilding will require long time periods.

The following sections discuss the general physical and biotic environments in which these Snake River salmon are existing.

Mortality at Dams

The 471 mile mainstem migration corridor of the Snake River from the Clearwater River to the Columbia estuary currently includes 330 continuous miles of eight reservoir habitats. The aggregate mortality of juveniles migrating through this corridor is estimated between 43 and 95 percent from all causes. A large body of literature exists on the extent of juvenile mortality for the *In-River Path.*

Examination of 1994, 1995, and 1996 survival data from PIT-tagged fish (NMFS) show that about 50 to 70 percent of the spring chinook juveniles released upstream of Lower

Granite Dam arrive alive at McNary Dam after swimming past the four Lower Snake River dams. Based on NMFS survival studies (1994, 1995, 1996) and acute mortality studies at the dams (Corps reports), the majority of the mortality occurs near the dams, either prior to, during, or just after passage. This suggests that we should focus our efforts around the dams (not the reservoirs) if we wish to improve the *In-River Path* for the juvenile stage. The one caveat is that if arrival time at the estuary greatly affects adult return rate, then migration rate past each dam is important.

In the lower Columbia River, we have limited PIT-tag data on juvenile survival to John Day Dam. The data for John Day and McNary suggest mortality in the Lower Columbia is similar to mortality in the Snake.

Mortality in Reservoirs

The amount of natural mortality in the system is not well-known, but limited data (Bennett; Iwamoto; Rieman; Poe in Harza, 1994; in Bevan, 1994) suggest there is between three to five percent average reservoir loss per project. This amounts to between 22 to 33 percent system mortality from predation, disease, and competition with other species. If the actual loss is close to 33 percent, we will need to eliminate virtually all dam mortality to achieve significant in-river survival rates (i.e., three percent increase per project).

Predation and competition existed prior to the dams but major changes are noteworthy. At least seven species of exotic fish have extensively colonized the Columbia and Snake. These species are successful predators and competitors for food and space. Secondly, man-made dams create more (lentic) low velocity habitat for non-salmonid and predatory fish (squawfish, catfish, walleye, small mouth bass). Finally, hydraulic passage at dams injures, disorients, delays, and concentrates migrants making them more vulnerable to predators.

Latent mortality is suspected from diseases like Bacterial Kidney Disease (BKD) and other known maladies. But, like predation, separating and estimating BKD losses from other sources of latent mortality is difficult. For analysis, it is probably best to assume that BKD-caused loss is absorbed in the predation load on the population because there is little we can do about it.

Delayed Mortality and Timing of Migration

Latent mortality from delayed migration is a controversial issue that must be resolved as part of evaluating both the *In-River Path* and the *Transportation Path*. Estuary arrival of in-

river migrants is delayed about a month due to reduced velocity through the reservoirs (see Bevan et al., 1994 for a discussion). Transported migrants arrive earlier than would be normal because a two-day barge trip shortens natural migration by several weeks. Estuary and ocean conditions vary from week-to-week and year-to-year. Salmon have evolved mechanisms to cope with this variation. Estuary and ocean survival depends on the coincidence of juveniles finding good food supplies (and other life support conditions) in the transition from fresh to salt water. Adults and juveniles can be found in rivers nearly every month of the year under natural conditions. Harvest also affects timing because if early returning adults are harvested more than late returning adults, this forces later spawning, hatching, and return of wild fish (Cramer, 1996). Our hatchery, harvest, barging, and hydropower system have inadvertently modified, restricted, and shifted the timing of migration.

To address this issue, we must understand whether we are actually affecting the return of adults by modifying the arrival of juveniles at the estuary. This question is important because we can modify juvenile migration timing arrival via drawdowns, surface collectors, and new transportation protocols. A comparison of survival among in-river with transported juveniles will not answer this question because while transportation may save some turbine or other dam-caused mortality, early or late arrival may subtract some of these benefits. Although in-river migrants may gain the benefits of a broadly timed, albeit shifted, window of arrival, they may lose a considerable portion of the population from dam related mortality. Thus, simple comparison of in-river survival vs. transport survival only compares *net benefits* of each but does not distill maximum potential, i.e., net maximum adult returns, from either strategy.

System Operation: 1996-1999

The existing system operation is described in the NMFS 1995 Biological Opinion. Essentially, the Corps of Engineers tries to operate the hydropower system with the following priorities: maintain reservoir pools at Minimum Operating Pool (MOP) during migration (April 15 to August 31); and bypass 80 percent of the juveniles away from the turbines. Currently this is attempted with spill and screens. Most of the existing screens keep about 50 percent of spring chinook and 70 percent of steelhead out of the turbines. Fall chinook are less efficiently guided. In 1995 Snake River dams spilled between 30-64 percent of the discharge. Higher uncontrolled spills occurred in 1996 due to unusually high runoff.

During average or low flow runoffs, if gas (TDG) levels rise too high, voluntary spill can be curtailed to prevent violation of regulatory standards. During high flow, involuntary spill

can cause uncontrolled violations of TDG. Current state laws call for 110 percent maximum TDG but NMFS has a permit for 120 percent in 1996. Spill may cause fewer juveniles to be barged. All test (PIT-tagged) fish that enter the JBS are returned to the river except for test groups placed in barges. Current transport protocols call for transporting most spring chinook and steelhead at the first three lower Snake dams. When fall chinook begin migrating, then the transportation program begins at McNary Dam. All fall chinook guided into the JBS are transported. Snake River fall chinook are not generally marked in large numbers.

Flow augmentation from storage reservoirs is mandated by the NPPC Fish and Wildlife Program which calls for an average monthly flow of 85 kcfs in the Snake with a goal of 140 kcfs during spring migration and 50 kcfs during summer migration. NMFS Proposed Recovery Plan is similar (spring 85 to 100 kcfs). Currently there is 10 MAF of storage allocated to augment flows during spring migration in both the Snake and Columbia Rivers aggregately. Flow augmentation can be requested by the Fish Passage Center to aid juvenile migration. Releases into the Snake are made principally from Dworshak Reservoir, but may also come from Brownlee through BPA power exchange agreements with Idaho Power Company or from BuRec uncontracted storage (90 KAF). The NPPC goal by 1998 is one MAF from the upper Snake basin above the current 4.27 MAF in Snake (NPCC's Strategy for Salmon).

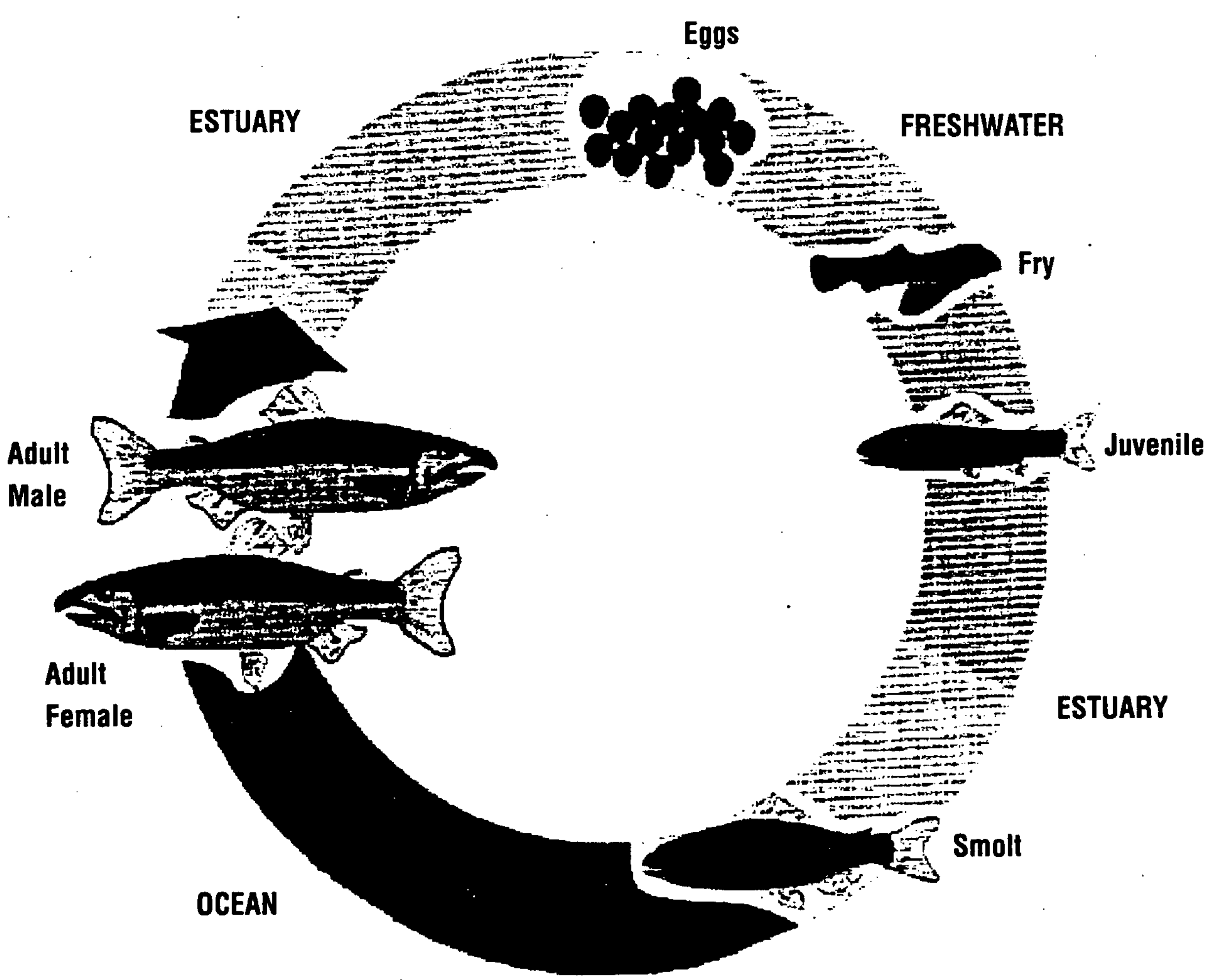
Habitat

Habitat is defined as the natural home or dwelling place of an organism. Because Pacific Salmon are anadromous, they require multiple habitats to successfully complete their complex life histories. Required habitats include freshwater rivers, brackish estuaries, and the oceans (Figure 3-6). Ideally corridors are uninterrupted and stress-free between habitats for adult and juvenile migrants. Rivers and lakes provide critical habitat for spawning and early-rearing, and rivers also provide the needed migration corridors mentioned above. Estuaries supply habitat for productive foraging, physiological transition between fresh and salt water, and refuge from predation. The ocean furnishes food supplies that are essential for growth and sexual maturity. It is the high productivity of the ocean that leads to rapid growth of anadromous species. Thus, because of their multi-habitat requirements, Snake River salmonids are significantly influenced not only by freshwater conditions but also by estuarine and marine conditions.

Until recently, the "H" that represents Habitat in the four "Hs" associated with salmonid declines, referred primarily to freshwater habitat. However, as our concern and knowl-

edge about dwindling salmonid stocks has increased, we now know more about the importance of estuarine and marine habitats and how their conditions influence salmonid health and abundance. Now we have to account for these habitats in our decision analysis. Therefore, we will present a summary description of existing physical and biological conditions in the Columbia River estuary and the Northeast Pacific Ocean, as well as describe river habitat, hatcheries, and harvest. We should add a fifth "H," Hydrology, because the flow volume of rivers changes seasonally and affects salmon habitat, salmon behavior, and salmon food (P. Klingeman, Oregon State University, pers. comm.; ISRG Report to NPPC, May 1996).

Figure 3-6: Typical Life Cycle of Anadromous Salmonids



River

Human-influenced and natural conditions in the Columbia-Snake River system have adversely affected the habitat and abundance of anadromous salmonid stocks that originate in the Snake River drainage. Human-influenced conditions include physical and biological changes. Some are relatively permanent. Others are temporary and can likely be improved over time spans that range from a few years to several decades. The climatic changes, which consist primarily of drought conditions that lead to reduced stream flows, are cyclic and are beyond human control.

A significant amount of spawning and early rearing habitat has been permanently blocked by the construction of large hydroelectric facilities that lacked viable fish passage systems. In addition, critical habitat has been eliminated by dam structures, reservoir creation, dredging and diking activities, wetland drainage, and riverside industrial, municipal, and recreational development. Other habitat has been degraded by past unregulated timber harvest and mining activities, construction of riparian transportation corridors, and by present releases of effluent from municipal and industrial water treatment plants and run-off from rural and urban lands.

Aside from habitat loss and degradation, human activities have adversely affected salmonid populations through unscreened irrigation diversions and reduced stream flows. In addition, the introduction of non-indigenous freshwater and anadromous fish species and hatchery-produced native species (see Hatcheries below) has caused significant changes in the native fish communities. These changes include increased incidence of predation, competition, and disease in salmonid populations, and possible interference with salmonid migration. The major species of concern include freshwater fish, such as walleye, smallmouth bass, and channel catfish, and the anadromous American shad. All are known predators and possible competitors of Snake River salmonids. The two to four million adult shad that annually migrate upstream through the fish passage ways of the lower Columbia River dams are believed to adversely affect the upstream migration of adult salmonids in fish ladders at the dams. Because freshwater fish species are naturally sparse, the presence of non-indigenous fish has greatly altered local aquatic communities.

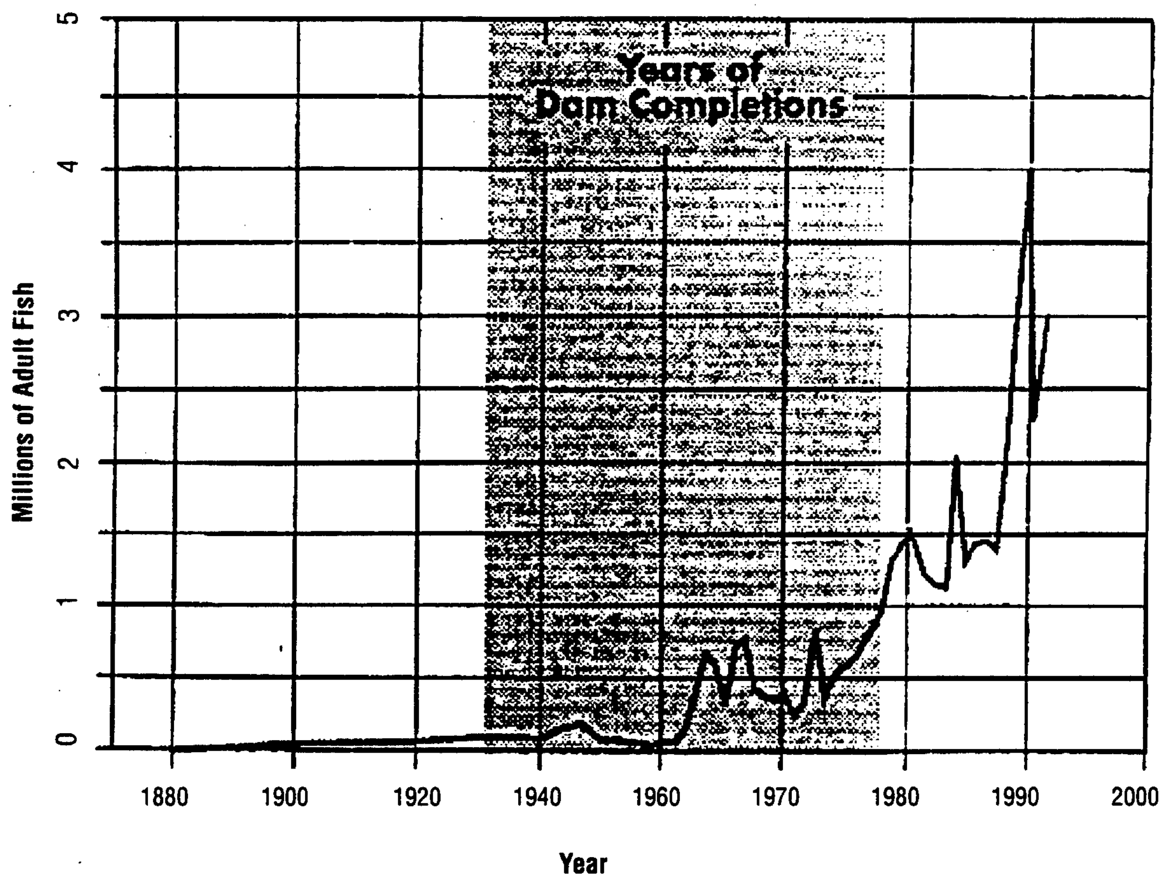
Columbia River Estuary and River Plume

Historically, the Columbia River estuary was an important feeding area for outmigrating salmonid smolts. Large changes in estuary morphology between 1867 and 1958, such as navigational improvements and diking and filling of much wetland areas (Sherwood et

al., 1990), have changed the estuary food base. Adverse changes in wetland habitat include an estimated 83 percent reduction in emergent plant production and a 15 percent reduction in bottom dwelling (benthic) macroscopic algae. At present, large amounts of plant fragments and debris (detritus) in the system is derived from microscopic plants suspended in the water column (phytoplankton). Phytoplankton have had a four-fold increase in the system because of large reservoirs created by dams on the Columbia-Snake River, while the macroscopic plants — and their detritus — that previously dominated the system are now greatly reduced in abundance (Simenstad et al., 1990).

Recently, Simenstad et al., (1990) found that small animals in the water column (zooplankton) associated with microscopic detritus accounted for 83 percent of total estuarine primary consumption, while bottom prey, including insects associated with macroscopic detritus of the estuary's wetlands, accounted for only two to 17 percent of this consumption. This shift in the food base, from macro-detrital consumption to micro-detrital consumption, means that about 83 percent of preferred prey of outmigrating salmonid smolts has been lost from the estuary. This change in the food base now favors juvenile American shad, which, as described above, are extremely abundant within the system and have an adverse effect on salmonid populations (Figure 3-7). Such a change and reduction in food may contribute significantly to poor ocean survival of juvenile salmonids and to recent declines in numbers of adult salmonids, including Snake River fall chinook salmon, which rely extensively on estuarine habitat during their juvenile state. Finally, nutrients in the Columbia River plume are essential to phytoplankton growth that supports salmonids during their ocean feeding migration. Storage reservoirs have reduced spring peak flows, which reduces the size and structure of the river's plume during smolt outmigration.

Figure 3-7: Minimum Number of Shad Entering the Columbia River



Sources: Chapman et al., 1991; WDF and ODFW, 1992

Physical Conditions in the Ocean

There is mounting scientific evidence that natural factors in the marine environment ultimately determine ocean productivity. These include climatic changes, related changes in atmospheric and sea-surface temperatures, *El Niño* events, upwelling conditions, and biological interactions and carrying capacity. Several researchers (e.g., Fisher and Pearcy, 1992; Francis and Sibley, 1991; Olsen and Richards, 1992) provide confirmation that ocean and climatic conditions greatly affect salmonid abundance and survival. Ocean productivity influences predator species and abundance, juvenile survival rates, adult body size, age of spawning, and ultimate size of returning populations that are available to harvest and that will provide spawners for future generations. In addition, wildlife manage-

ment decisions to protect and enhance marine mammals and seabirds that are known salmonid predators and competitors may have affected salmon predation and competition.

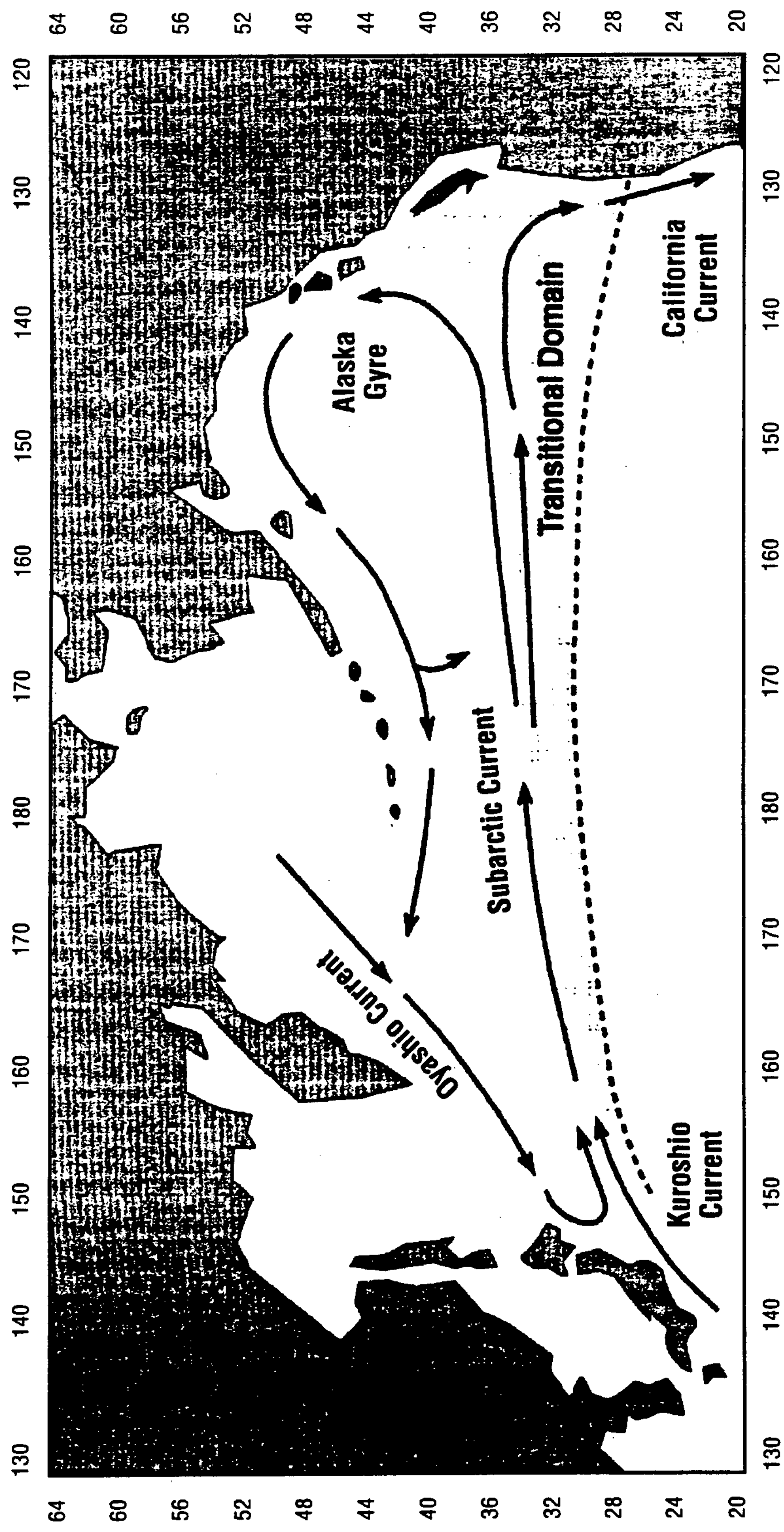
Regime Change in the Northeast Pacific Ocean

A major change in global climate occurred in the winter of 1975 to 1976 (Graham, 1995). This change produced unfavorable marine conditions in the Northeast Pacific Ocean for salmonid production in the area south of Vancouver Island (the Coastal Upwelling Domain), and highly favorable conditions farther north in the Gulf of Alaska (coastal Downwelling and Central Subarctic domains) and the Bering Sea (Figure 3-8 and Figure 3-9). High sea levels and warm surface temperatures along the coast, an intense Aleutian low pressure system, and weak upwelling conditions have been associated with these changes since 1976. During the 1960s and early 1970s, when releases of hatchery-produced salmonid smolts were increased to compensate for lost freshwater habitat in the Pacific Northwest, the opposite trend prevailed, with good ocean survival for salmonids south of Vancouver Island and poor survival for those in the Gulf of Alaska (Figure 3-9). Although the mechanisms that affect salmon production are still speculative, ocean climate is clearly implicated and should be considered in management decisions.

Anderson (1996) has concluded that favorable climatic and ocean conditions masked the original adverse salmonid impacts of hydroelectric development on the Columbia River between the 1940s and 1970s, and now poor ocean conditions are masking the recovery effects of salmonids expected from smolt barging and turbine improvement activities on the river. Beamish and Neville (1996) concluded from their research that the regime change of 1976 altered the productivity trends of a number of commercially important fishes. The effects were particularly noticeable in salmon stocks. The productivity of pink, chum, and sockeye salmon stocks reared in the subarctic Pacific increased, while the productivity of coho and chinook salmon stocks in the Strait of Georgia and probably off the coasts of Washington and Oregon decreased.

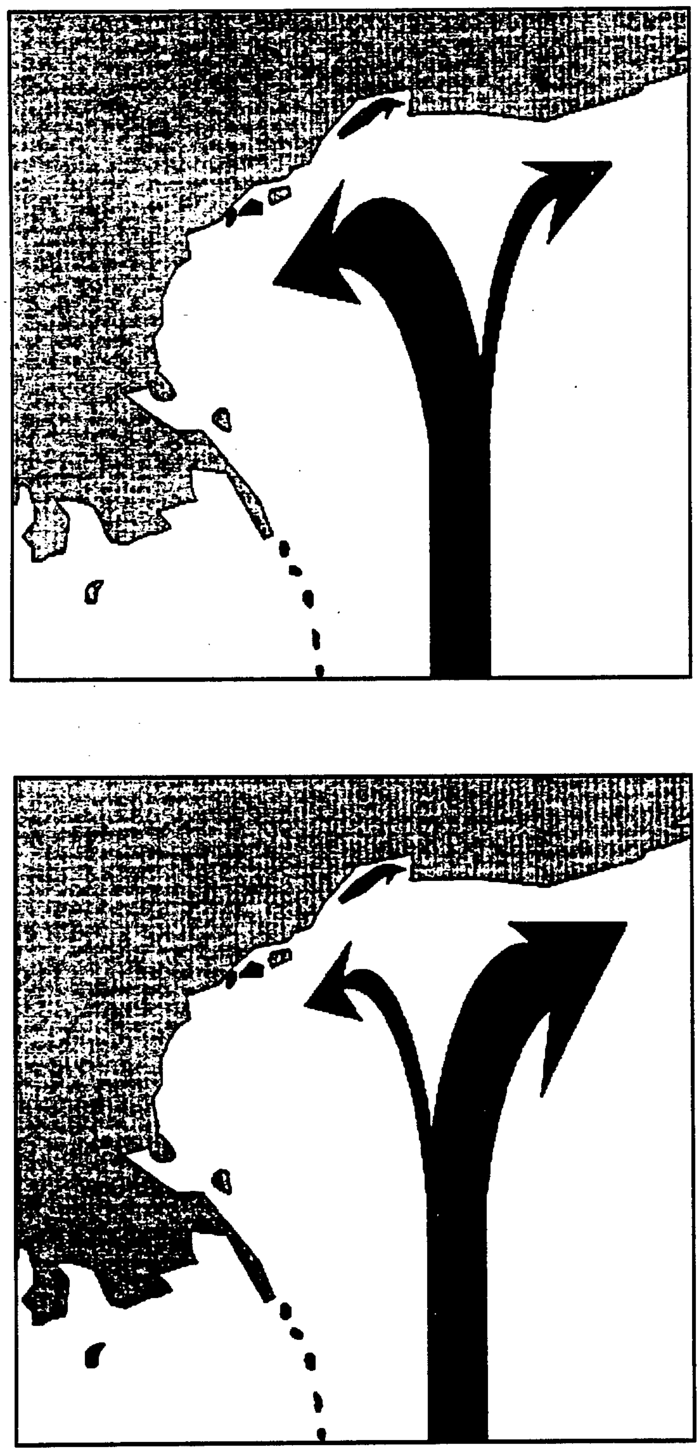
The previous major change in the climatic regime of the Northeast Pacific Ocean occurred in the mid-1940s. From then through the mid-1970s, the ocean south of Vancouver Island was very productive for salmonid stocks that originated from California, Oregon, and Washington, while salmonid production of Alaskan stocks was poorer. These periodic shifts in ocean productivity are supported by similar shifts in harvest levels of Oregon and Washington coho salmon and of Gulf of Alaska pink salmon, as demonstrated in Figure 3-10.

Figure 3-8: General Surface Circulation of Northeast Pacific Ocean



Source: Pearcy 1994

Figure 3-9: Change in Ocean Productivity



Pre 1976

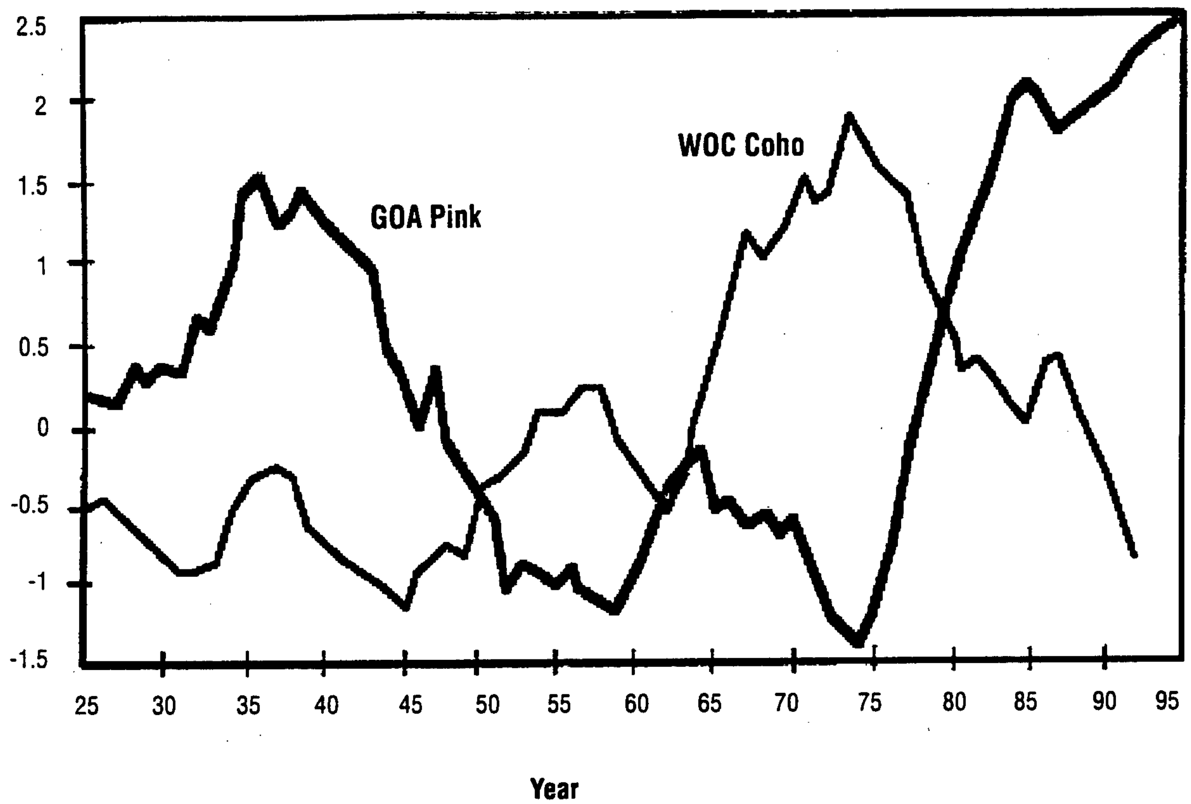
Oregon Coho Salmon
Ocean Survival ~ 8%

Post 1976

Oregon Coho Salmon
Ocean Survival < 3%

Source: Pearcy 1994

Figure 3-10: Catch of Pink Salmon (Alaska) and Coho Salmon (Oregon, Washington) 1925-1995



Source: After Francis and Sibley, 1991

Climatic Warming and Ocean Effects

Oceanic and atmospheric circulation are closely related, and enormous amounts of heat are continually exchanged between these two environments. Several technical articles recently published in the journal *Science* provide compelling scientific evidence that climatic warming, and subsequent warming of sea surface temperatures, are significantly affecting the abundance and distribution of marine organisms. Temperature conditions appear to have a significant effect on the abundance of prey that comprise the food chains and food webs of the Northeast Pacific Ocean, and ultimately on the marine and anadromous species that rely on these prey — including Pacific salmonid stocks — and on the species and abundance of salmonid predators (Welch, 1996).

Graham (1995) confirmed that average global atmospheric temperatures have been rising

during the past century, with the most recent portion of the record showing a sharp rise since the mid-1970s. The overall increase since the 1970s has averaged about 1.8° F. Graham further reports that although it is possible that these increases in temperature could be a result of natural climatic variability, there is the "disquieting" possibility that they could be caused by increased atmospheric carbon dioxide levels that are related to human activities ("greenhouse effect"). Barry et al., (1995) reported that changes in intertidal marine communities in California between the 1930s and 1990s were correlated to the increases in nearshore ocean temperature. Annual mean water temperatures at the site increased by 1.4° F during the past 60 years, and the mean summer maximum temperatures from 1983 to 1993 were 4° F warmer than for the period from 1921 to 1931. Roemmich and McGrowan (1995) have shown that the biomass of zooplankton in the California Current has decreased by 70 percent since 1951. During this same time period, the surface layer of the California Current warmed, in some areas, by more than 2.7° F. The authors predict that continued warming could lead to further declines in zooplankton biomass. The significance of these findings to salmonid stocks is at least three-fold:

1. Increases in sea surface temperatures in parts of the Northeast Pacific Ocean have been reducing the abundance of zooplankton, which forms the basis of all salmonid food webs. Thus, these ocean conditions are at least partially responsible for associated declines in salmonid abundance because salmonids reach sexual maturity and gain 95 percent of their body weight while foraging in the marine environment (Pearcy, 1994).

2. Temperature increases are apparent both in near-shore, coastal, and offshore pelagic waters. Such changes may be affecting juveniles that feed in estuarine and near-shore environments, and subadults and adults that feed in coastal and pelagic areas.

3. Whether the temperature increases are natural or human-influenced, the current trend appears likely to extend at least into the near future. This suggests that low levels of productivity in the Northeast Pacific Ocean, and low abundance of Pacific Northwest salmonid stocks, may also continue to occur either in localized coastal areas or over wider expanses of pelagic waters.

Ocean Upwelling

The upwelling of nutrient-rich bottom waters to the sea surface in coastal areas greatly affects ocean productivity. These nutrient leaden waters promote phytoplankton growth, and the subsequent growth of zooplankton and larger animals. Upwelling is "driven" by offshore winds. As the surface water moves offshore it is replaced by colder, deeper water that moves onshore and eventually rises to the surface near the coastline, and itself is

transported offshore (Figure 3-11). Downwelling, caused by onshore winds, is exactly the same process as upwelling but in the opposite direction (Figure 3-11). Because *El Niños* can affect local climate and resulting weather and wind patterns, they can weaken or essentially eliminate upwelling in *El Niño*-affected regions of the Northeast Pacific Ocean. In general, upwelling is relatively strong and constant along the West Coast, south of Cape Blanco, Oregon. Upwelling to the north is episodic, seasonal, and weak. Upwelling becomes strong again along the west coast of Vancouver Island, British Columbia. To the north, coastal waters are typified by downwelling.

El Niño Events

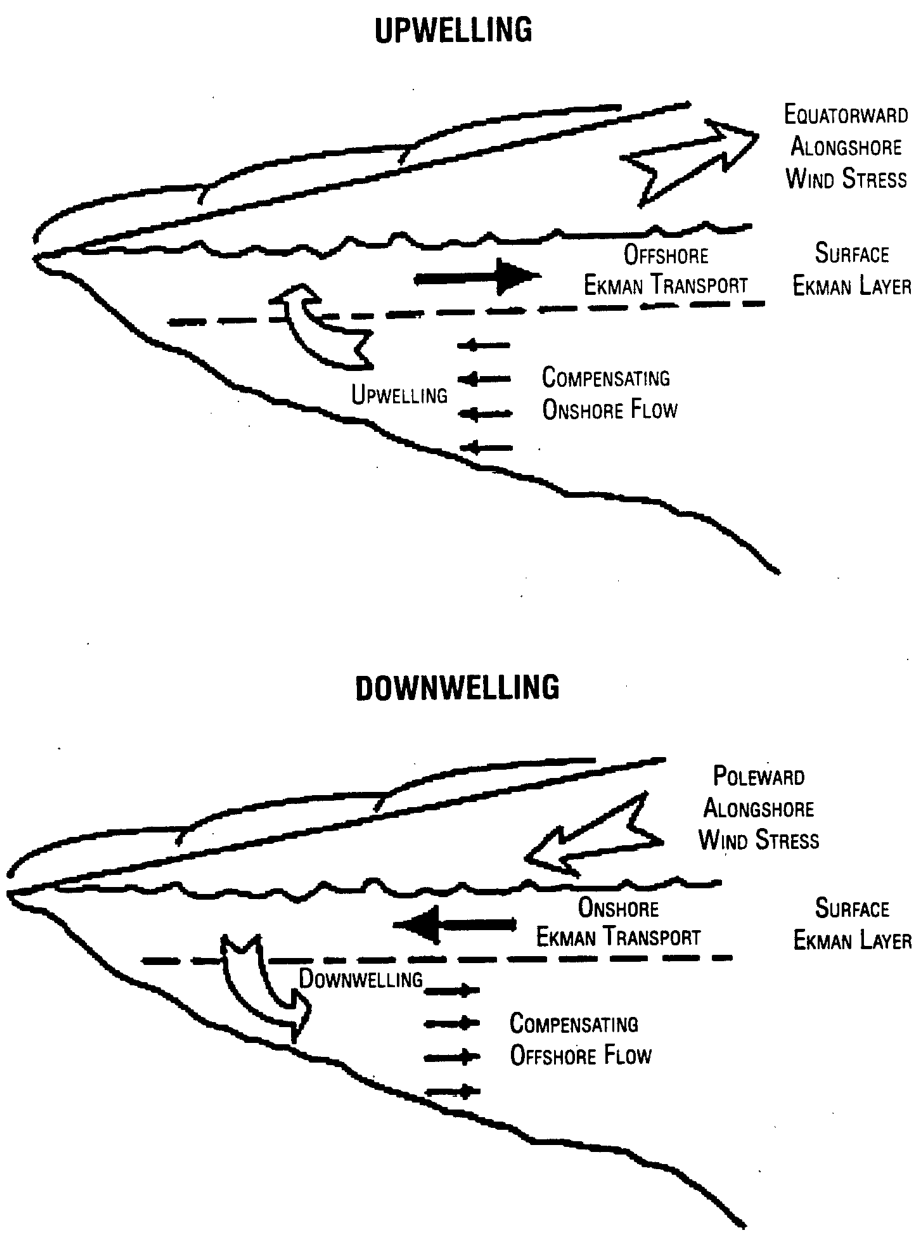
Periodically, a reversal occurs in tropical Pacific wind and ocean currents. This phenomenon, termed *El Niño*, brings warm, nutrient poor and low salinity (less dense) southern-ocean surface waters and easterly winds to the West Coast of the Americas and increased sea-surface height (Jacobs et al., 1994). Upwelling, and subsequently primary productivity, is depressed during *El Niño* events, which has important consequences for fish populations. *El Niños* may also alter local rainfall patterns and air temperatures. This can lead to inland drought conditions, which also can affect stream flow levels and salmonid survival and production.

The strongest *El Niño* of this century occurred in the North Pacific Ocean during 1982 and 1983 (Jacobs et al., 1994) and its effects on ocean productivity and climate were still apparent a decade later (ibid., McPhaden, 1994). A weaker event occurred in 1992. Other major events of the past 50 years occurred in 1941 and 1957-58. During *El Niño* events, salmon production in the coastal waters off Oregon and Washington decreases substantially (Pearcy, 1992). The Oregon ocean troll fishery in 1983 was down 38 percent for chinook salmon, and 57 percent for coho salmon, compared with 1971 to 1975 average catches. The effects of *El Niño* are generally, but not always, most severe on salmon stocks that show localized ocean distribution.

Ocean Carrying Capacity

The ocean's carrying capacity for anadromous salmonids is dynamic in time and space. It is constantly changing on interannual, decadal, centennial, and millennial time scales (Pearcy, 1996). Scientists have increasing amounts of evidence, that food at times may be limiting in the marine environment. We will present evidence below that the present number of natural and hatchery-produced salmonid smolts in the Columbia-Snake River

Figure 3-11: Diagram of Upwelling and Downwelling Conditions in Coastal Waters



system is in excess of historical smolt numbers. Together with juveniles of forage and commercial species, and the annual addition of several hundred million juvenile American shad (Palmisano et al., 1993), the food supply may be incapable of adequately nourishing this large number of juvenile salmonids.

Each year Japan, Russia, Canada, and United States release a combined total of five billion juvenile salmonids into the North Pacific Ocean (Pearcy, 1992). Concern exists that continued releases of large numbers of hatchery-produced salmonids may be stressing the system's food supply. Pearcy (ibid.) noted that salmonid stocks from both Asia and North America acquire more than 95 percent of their growth in the North Pacific. Evidence from large releases of chum salmon from Japan, and pink salmon from Alaska, shows that average weights and lengths of returning hatchery-produced and wild fish, have decreased significantly (ibid., WDF 1992).

Marine Predation and Competition

Another recent change in marine conditions is the annual three to 12 percent increase in the abundance of seal and sea lion populations that has occurred in the Pacific Northwest since the U.S. Marine Mammal Protection Act was passed in 1972 (Table 3-1), and similar legislation was passed in Canada shortly later (Olesiuk et al., 1990 a,b). The harbor seal populations in British Columbia have increased from 9,000-10,500 animals in 1970, to 75,000-88,000 by 1988 (Olesiuk and Bigg, 1988). Olesiuk and Bigg believed that the population may have been at or near carrying capacity, and that numbers approached, or actually exceeded, historic levels. Harbor seal populations have doubled since the 1970s in Oregon and Washington. Today the Oregon population is over 12,000 animals and the Washington population is about 38,000.

Table 3-1: Recent Increases In Marine Mammal Population Size in the Pacific Northwest

Harbor Seals				
British Columbia	1970	9,000 - 10,500	1988	75,000 - 88,000
Washington	1972	2,000	1992	38,000
Oregon	1984	4,000 - 5,000	1992	9,500 - 12,200
California Sea Lions				
United States West Coast	1978	36,000	1988	67,000
Killer Whales				
British Columbia and Washington	1970s	190	1986	240

The West Coast population of California sea lions from Mexico to Canada is about 180,000 animals (U.S. Department of Commerce, 1988). This includes about 67,000 sea lions in the U.S. population that has increased at an annual rate of six percent over the last decade

(Boveng, 1988). Killer whale populations in coastal waters of British Columbia and Washington increased from about 190 animals in the early 1970s to about 240 in 1986 (Olesiuk et al., 1988).

Marine mammals have always preyed on salmon. Thus, recent increases in marine mammal numbers may not be the major cause of current salmonid declines, but it could be contributing to the problem of recovery. Seals and sea lions are known to prey on adult, subadult, and juvenile salmonids, and on species that are important salmonid prey (Olesiuk and Bigg, 1988; Olesiuk et al., 1990b). Salmonids comprise five to 10 percent of the annual diet of harbor seals and California sea lions, while the remaining diet of these pinnipeds is primarily comprised of bait fish (such as, herring, smelt, and anchovy) and invertebrates (squid) that are routinely selected by salmonids. The decline in the annual harvest of Washington baitfish, from almost 14 million pounds in 1975 to less than two million pounds in 1990 (Table 3-2), could be a combined result of the effects of increased abundance of marine mammals since 1972 and the decline in regional ocean productivity since 1975. It also reflects reduced harvest effort.

Pinnipeds follow adult salmonids into freshwater environment, as far as Bonneville Dam in the Columbia River system. Bite marks, scratches, and scars attributable to either sea lions or harbor seals have been observed on upstream-migrating spring chinook salmon in the Snake River. Chapman et al., (1991) estimated that 19 percent of fish passing Columbia River dams in 1990 had "seal marks." An estimated 40 to 50 percent of observed adult spring chinook salmon ascending the fish ladder at Lower Granite Dam on the Snake River in 1990 had teeth marks and scars attributable to pinnipeds (Harmon and Matthews, 1990). Recent observations represent a significant increase over those of past years. Everitt et al., (1981) reported that only 0.4 percent of almost 330,000 salmonids of four species examined by fish counters at Bonneville Dam had marks attributed to seals during 1980 (see Table 3-3).

Other managed or protected marine mammal (killer whales, northern sea lions, and harbor porpoises) and seabird (cormorants and murres) species are known estuarine and marine predators and competitors of young and adult salmonids. Predatory, commercially important fish species, such as mackerel and hake, are more abundant during warmer ocean conditions, and are known to prey heavily on Pacific Northwest salmonids (Welch, 1996; Pearcy, 1996).

Table 3-2: Washington Commercial Landings of Baitfish by Species from 1975 to 1990

(Thousands of Pounds) Source: WDF (1992)

Year	Herring	Surf Smelt	Anchovy	Total Baitfish
1975	13,141	81	630	13,852
1976	5,915	85	415	6,415
1977	6,665	113	317	7,096
1978	6,467	78	12	6,556
1979	7,766	94	0	7,860
1980	6,996	61	0	7,057
1981	2,565	63	3	2,632
1982	2,458	90	11	2,559
1983	1,914	62	6	1,982
1984	852	92	22	966
1985	929	91	26	1,046
1986	1,210	133	49	1,392
1987	1,209	136	171	1,516
1988	1,853	159	89	2,101
1989	1,513	100	136	1,749
1990	1,616	60	111	1,787

Table 3-3: Percentage of Adult Salmonids in the Columbia Basin with "Seal Bite" Marks

Year	Species	Sample Location	Scar/Wound Incidence	Sample Size
1980	Salmonids	Bonneville Dam	0.4%	330,000
1990	Salmonids	Columbia River Dams	19%	242,000
1990-92	Chinook	Lower Granite Dam	40-50%	1,700-3,200

Hatcheries

Artificial propagation has often been perceived as a way to perpetuate fish stocks that have suffered from habitat loss and over exploitation. Newly gained in-sights of hatchery-produced fish suggest that these programs not only may fail, but may pose the greatest single threat to the long-term maintenance of salmonid stocks in the Pacific Northwest. If used properly, however, hatchery-produced fish may mitigate the loss of wild fish stocks and even revitalized the gene pool of stagnant stocks. Today, hatchery-produced salmonids comprise over 80 percent of Snake River and over 75 percent of Columbia River stocks. In addition, McIntyre (1985) has noted that many more salmonid smolts now enter the ocean from the Columbia-Snake River than at any time in the past. These drastic changes have undoubtedly affected the gene pool, viability, health, and abundance of the system's remaining salmonid stocks.

Because stocks used in the Pacific Northwest for artificial propagation of salmonids have not always been matched to the environmental and genetic requirements of the wild stocks they replaced, hatchery-produced fish that spawn in the wild could be impacting wild stocks.

The Northwest Power Planning Council (1986) estimated that annual salmonid smolt abundance was 264 million fish before 1850. Since the late-1980s, public hatcheries in the Columbia River basin have annually reared between 200 and 300 million juvenile salmonids for release into the basin (Schiewe et al., 1989). Based on hatchery releases of nearly 203 million fish and an estimated 145 million naturally-produced fish, a total of almost 348 million salmonid smolts were present in the basin in 1992 (Table 3-4). This is 32 percent above estimated smolt numbers prior to 1850, yet adult returns remain low (Table 3-4). Such large numbers of outmigrants place a large demand on food production capabilities of the Columbia River and estuary. McCabe et al., (1983) showed the existence of a significant diet overlap among subyearling and yearling chinook salmon, coho salmon, and steelhead trout in the estuary during spring, even in the 1980s. It is quite possible that releases of large numbers of Columbia River smolts during the late 1980s and 1990s are affecting Snake River chinook salmon.

Hatchery-produced fish are fed daily to satiation to maximize smolt size before release. Therefore, they are larger and can often out-compete their wild counterparts of the same age. Because hatchery-reared fish are spared the rigors of nature during early development and rearing, their survival rates, hence numbers from egg to smolt, are much greater than those of wild fish. Many of these smolts perish during the migration. If and when prey is

limited, large releases of hatchery-produced fish may cause food shortages for wild stocks, or attract large numbers of predators that further reduce wild salmonid abundance. In addition, hatchery-produced salmon, because of their large size, directly prey or injure the smaller wild salmon smolts. All the above factors may cause fewer wild fish to return.

Table 3-4: Estimated Columbia Basin Salmonid Smolt Production and Run Size of Returning Adults

(in millions of fish)

Era	Wild Smolts	Hatchery Smolts	Total Smolts	Adult Run Size	% Adult Return
Historical	265	—	265	7.5	2.8
1992	145	203	348	1.2	0.3

Rearing hatchery-produced fish can intensify the incidence of a variety of naturally occurring salmonid diseases. Subsequent releases of diseased hatchery-produced fish could transmit these infectious diseases to wild fish, and significantly reduce wild stock abundance.

Freshwater survival rates for hatchery-produced juveniles (prior to release) fish are about 80 percent compared to two to 10 percent for wild fish (prior to migration). Depending upon the rate of ocean survival, this allows harvest rates up to 80 to 90 percent for hatchery-produced fish versus 40 to 75 percent for wild fish. If both hatchery-produced and wild stocks occur together in the fishery (mixed-stock fishery) that is fished at the harvest rate of the hatchery-produced fish, the wild stocks could be over fished. If these mixed stocks are fished at the wild-stock rates, too many hatchery-produced fish will escape the fishery. Some of these excess fish will stray or could be intentionally released to mix with wild stock. This could further reduce the genetic adaptability of wild fish to the natural environment.

Harvest

Species of Snake River salmon have been reduced to a small fraction of their former abundance. Reduced abundance and protection under the U.S. Endangered Species Act have reduced or eliminated legal harvests in the U.S. There are essentially no Snake River sockeye salmon left to harvest. In-river commercial fishing has not occurred since this species was listed in 1991.

Currently, less than one percent of all spring chinook salmon that survive to catchable size are harvested in the ocean. The ocean harvest occurs mainly in the British Columbia troll and net fisheries (Berkson, 1991). The Pacific Salmon Commission (1990) reported that spring chinook salmon are not a significant part of ocean commercial troll and recreational fisheries. In-river fishing of summer chinook salmon has been closed to commercial harvest since 1963, and has not been allowed in any recreational harvest since 1974.

Except for an eight-day fishery in 1977, tribal fishermen have not been allowed a commercial season for spring chinook salmon since 1975. Ceremonial and subsistence fishing is conducted each year on adult chinook salmon, with the majority of the catch taken from the spring run. Summer chinook salmon have not been targeted by tribal fisheries since 1964, but were incidentally caught during sockeye salmon and American shad seasons periodically from 1965 to 1973, and from 1984 to 1988. Some tribal harvest of chinook salmon occurs on Snake River tributaries, such as the Grande Ronde, Clearwater, Imnaha, and Salmon River.

Snake River fall chinook salmon are harvested in the ocean from Alaska to California, and in the Columbia River. The fish are harvested by U.S. and Canadian commercial and sport fisheries and by U.S. tribal fisheries. Most are harvested in the British Columbia troll fishery, and in the Columbia River Indian net fishery. They are also taken in the Washington-Oregon troll fishery, and in the Columbia River non-Indian net fishery. Recently, total harvest rates have declined to 61 percent in 1991, 46 percent in 1992, and 53 percent in 1993 (Bevan et al., 1994).

Section 4

TOOLS FOR SALMON RECOVERY

Section 4 TOOLS FOR SALMON RECOVERY

Lower Snake River

The U.S. Army Corps of Engineers is currently making changes at the dams in response to NMFS Biological Opinion. Table 4-1 lists the 1997 Preliminary Plans of Action for the Walla Walla District.

Table 4-1: USACE Salmon Improvements via Construction (BiOp Measure VIII) or Study (BiOp Measure X)

Construction Program (VIII)	Goal
Fish Transportation Improvements	Continue and Study
MOP Operation	Operate Reservoirs at Lowest Functional Level
Turbine Operation	< 1 percent from Peak Efficiency
Fish Facility Operation	Operate at Agency Criteria
Reduce Adult Fallback	Study Recommended Measures
Barge Exits	Construct Enlarged Openings
Drawdowns	Study
Surface Collection	Test Prototype at LGR
Dissolved Gas	Monitoring Program
Extended Length Screens	Install at LGR, LGO, and MCN
LGR Juvenile Facilities	Improve
More Barges	Construct

Study Program (X)	Goal
Adult Spill Patterns	Improve Adult Passage
Adult Passage	Study, Ladders, etc.
Fall Chinook Spawning	Continue to Search and Monitor
Turbine Passage	Reduce to 5% or less
Regional Research Facility	Plans for Fish Passage Study Center
Snake River Temperature	Develop Model

Except for drawdown, surface collectors, and Snake River temperature modification, all of the measures are minor modification or analyses of the existing *In-River* or *Transportation* paths. What is needed is an evaluation of major modifications that will significantly address the question of recovery. Drawdowns, especially natural river, could supply up to a 10 percent juvenile survival benefit and up to a three percent adult survival benefit per project. Surface collectors could supply a three percent juvenile survival benefit per project. It is hypothetical that Snake River temperature modification could prevent adult delay or mortality during spawning migration. Drawdowns and surface collection are discussed in this report. Temperature modification may need biological corroboration and might require dramatic flow changes. This could be significant but is beyond the scope of this report.

Lower Columbia River

Currently there are surface collector studies in progress to improve juvenile bypass at John Day, The Dalles and Bonneville hydroelectric projects. Baffled spillways are being studied at The Dalles to evaluate improved Fish Passage Efficiency (FPE) (more fish with less water) through the spillway. Finally, optional outfall structures are being studied for Bonneville.

Future Alternative Hydroelectric Project Improvements

The following list is a summary of the major system configuration and operational changes proposed to improve salmon survival past the four lower Snake and four lower Columbia hydroelectric projects.

Physical Changes

1. **Surface Collection.** This is any structural modification to allow juvenile fish to pass downstream of a powerhouse via an unpressurized surface oriented exit. Surface bypass is designed to pass more fish in less time with less harm than traditional screened turbine intakes. The surface collector releases fish directly to the river but could be designed to dewater fish into barges. The surface collector at Lower Granite reservoir will cost approximately $18 to $25 million to construct and may require up to 12,000 cfs to operate.

2. **Baffled Spillways.** This is a bulkhead inserted upstream of tainter gates that enables surface waters to be drawn past spillway gates. Surface spill has been shown to have higher fish passage efficiency than deeply located intakes at several prototype projects. The goal is to have more fish pass the project in shorter time with less water. In addition to reducing energy loss, baffles may also reduce nitrogen gas supersaturation. Baffles will cost about $500,000 per spillbay plus lost energy from spill. If successful, baffles could be paid for by incremental hydropower benefit (over 1995 BiOp spill) in less than one season of operation.

3. **Extended Length Screens.** These are screens that intercept a greater percentage of the turbine intake than existing screens. It is estimated that these screens will increase fish passage efficiency by 20 to 30 percentage points. Existing screens prevent about 50 percent of spring migrants and 35 to 40 percent of summer migrants from entering turbines. These cost about $26 million per project and were installed at Lower Granite in 1996.

4. **Spillway Modifications.** Concrete deflectors called flip lips have been used to reduce nitrogen supersaturation from spill operations. These and other spillway modifications are proposed to reduce TDG. Costs are about $25 million per project. Although partially efficient at reducing TDG, flip lips do not eliminate the TDG problem. Additionally, preliminary tests at Wanapum Dam showed juvenile mortality increased when flip lips were added to spillbays (pers. comm., BPA). The Corps is also investigating modifying the stilling basin at Snake River projects. Ice Harbor Dam will have flip lips in 1997. These shallower designs would cost about $36 million per project.

5. **Turbine Modifications.** Turbine efficiency is a measure of how much energy is produced from a specific amount of water. Fish survival is believed to be correlated with efficiency. Turbine rehabilitation benefits both energy output and survival of fish passing through turbines. New designs are being developed for future deployment. With only 20 to 30 percent of fish passing turbines and a 10 percent mortality, improvement potential is limited to only about one to two percent increase in juvenile survival per project. Because new turbines may return higher energy values, marginal fish benefits may be more economically attractive.

6. **Fish Guidance Curtain.** This is a hypalon sheet that hangs vertically in the river. Its purpose is to guide fish toward fish passage structures and increase FPE. The Walla Walla District began preliminary design for a prototype at Lower Granite. Originally budgeted for $6 million, it was cut from the 1996-1997 budget. Such a device, should it be developed, is experimental. The goal would be to increase FPE without affecting the other measures such as spill.

7. **Adult Fishways.** Adult salmonids pass dams by entering fish ladders in the tailwater and exiting them in the reservoir forebay. Reservoirs are being operated below normal pool levels (minimum operating pool or MOP). Agencies have reported several concerns including: (1) inability of adults to find entrances, (2) inappropriate hydraulic or thermal conditions (criteria) in the ladder that discourage rapid passage, and (3) the potential for fallback to tailwater through turbines due to inappropriately located exits. Studies are proposed to evaluate and correct such problems. MOP operation provides very minor water particle travel time benefits and unprovable juvenile fish benefits (Harza, 1994). If it causes adult migration problems, it may be a greater population detriment.

8. **Juvenile Bypass Systems.** Juveniles that encounter turbine screens pass through a series of hydraulic passages that screen and dewater fish. Various physical problems are known to exist in JBS's including predators, juvenile delay, excessive water temperatures, improper holding facilities, improper handling procedures, and physical injury due to unfriendly hydraulics. Various analyses and/or changes are proposed. Currently, juvenile mortality through JBS systems is estimated at one to two percent.

Operational Changes

9. **Spill.** National Marine Fishery Service (NMFS) has dictated, in its 1995 BiOp and draft Recovery Plan, the use of spill as an interim measure to protect downstream migrating juvenile salmon. Spill levels are variable in both location and timing but are geared to achieve 80 percent FPE. They are constrained by water quality regulations limiting nitrogen supersaturation because high gas levels are known to be biologically harmful. Spill may be the most expeditious means to achieve 80 percent FPE because no construction is required. However, exceeding the TDG standard may preclude achieving 80 percent FPE target at most dams. The Dalles, with its shallow stilling basin, is a noteworthy exception.

10. **Transportation.** This is the loading of migrating juveniles into barges at upstream dams and moving them past downstream dams where they are released back to the river. Modification of both procedures and facilities are planned as well as monitoring and evaluation. Direct barge loading of migrants (no delay) and sorting large from small fish may improve the survival of transported fish. NMFS is continuing to monitor juvenile survival and adult returns. We do not expect major improvement in adult return rate because the existing system already shows high survival of transported juveniles.

11. **Storage.** The use of water stored behind dams (especially Dworshak, Brownlee and Grand Coulee) has been used primarily for the purpose of flood control and power genera-

tion and secondarily for fish migration purposes. Reservoir operations are changing to improve in-river conditions for migrating fish. Additionally, the search for new storage and or purchase of existing storage rights is being studied. Currently, the 1995 BiOp requires up to 10 to 12 MAF of storage be used for fish migration. The estimated energy losses are about $10 million per MAF.

Monitoring and Evaluation

12. **In-River Survival Studies.** Using PIT tags and other technologies, it is possible to monitor the survival of juveniles and adult return rates from various downstream passage routes. Using these methods, it is possible to evaluate the benefits of being in-river compared to in-barge. Additionally, in-river survival studies can be used to compare baseline (1993 to 1995) conditions to modified system configurations and operations in 1996 to 1999 and beyond, if desired.

13. **Fish Passage Survival Studies.** Using balloon tags, radio tags, PIT tags and other technologies, it is possible to monitor fish passage efficiency, fish guidance efficiency, survival rate and travel time through new structures such as baffled spillways, surface collectors and extended length screens. Such studies should be designed to test the efficiency of achieving NMFS's 80 percent FPE goal and NMFS's 95 percent juvenile survival goal at each dam. If a technology does not meet criteria in a reasonable test period, it should be abandoned.

14. **PIT-Tag Detection Facilities.** These are electronic sensors that detect and identify fish with special tags inserted into the body cavity. To evaluate juvenile survival rates in the lower Columbia and to better assess adult returns, plans exist for new facilities at Bonneville and John Day dams. Cost is principally tied to dewatering fish. Costs ($16 to $20 million) and time delays (two to three years) have been excessive. Simpler designs with relaxed criteria could reduce both cost and delay. Adult PIT-tag detectors are needed to address the issues of adult inter-dam losses and homing impairment.

Section 5

IN-RIVER PATH

Section 5 IN-RIVER PATH

Seven Possible Options

The *In-River Path* is defined as an uninterrupted salmon migration through the 330-mile long hydropower corridor from the head of Lower Granite reservoir to the tailwaters of Bonneville Dam. It means facilitating the "natural" migration of juveniles from freshwater to the estuary and also the spawning run of adults back to natal areas. It entails either removing existing Snake River dams or enhancing in-river migration past the dams. The latter could include changes at the dams, powerhouse, spillways, or storage facilities. The goals are to maximize juvenile survival through the corridor and minimize delay during migration. Prior to 1972, juvenile salmon passed dams via principally turbines and secondarily spillways. Adults have always migrated upstream past dams via fish ladders.

In 1969, the Corps of Engineers began testing, and in 1972 installing, turbine screens and transportation systems at the Lower Snake River dams. Until the 1995 NMFS BiOp, it was standard procedure to transport most juveniles captured. Capture efficiency and rules of transportation have changed over time. Agencies and tribes have generally viewed transportation as an "interim tool only" not a desirable mitigation method. Their concerns include physical injury to fish, crowding, handling, delay, improper temperatures, inadequate river flows, and predation associated with the dams and juvenile transport facilities. In addition, they cite statistically inadequate evidence that returning adults that were transported as juveniles show impaired homing ability.

The agencies and tribes have requested better in-river conditions to facilitate juvenile migration. These are: (1) increased flows from storage (April 15 to August 31); (2) spill at the dams; (3) improved turbine design; (4) improved screens; and (5) reduced gas levels from spill.

The purpose of this section is to review possible options to improve the *In-River Path*. We describe seven options (Table 5-1). Five involve drawdowns; only two involve maintain-

Table 5-1: Columbia River System Operation Review Alternatives

FIVE DRAWDOWN ALTERNATIVES

1. Seasonal Natural River Operation

What:	A lower Snake River drawdown.
When:	4.5 months, from April-August
How:	Reservoirs would be lowered to the original riverbed level and the river would flow through new outlets at each existing hydroelectric project.
Reference:	SOR 5b

2. Permanent Natural River Operation

What:	Drawdown of the lower Snake River (Lewiston to Ice Harbor Dam) to the original riverbed.
When:	Year-round.
How:	Sections of the embankment dam at each Snake River project would be removed to re-establish the Snake River near its historic level.
Reference:	SOR 5c

3. Seasonal Partial Drawdown

What:	Drawdown at all four lower Snake River projects.
When:	4.5 months (April-August).
How:	Each reservoir would be lowered about 30-35 feet.
Reference:	SOR 6b.

4. Permanent Partial Drawdown

What:	Lower Granite Reservoir Drawdown
When:	4.5 month (April-August).
How:	The reservoir would be lowered to about 35 feet below MOP.
Reference:	SOR 6d.

5. Detailed Fishery Operation Plan (DFOP)

What:	Establishes flow targets measured at The Dalles, includes seasonal partial drawdown of the lower Snake River projects.
When:	4.5 months (April-August).
How:	Sets spill percentages to limit gas supersaturation and eliminates fish transportation.
Reference:	SOR 9a.

TWO NON-DRAWDOWN ALTERNATIVES

FISHPASS

What:	Improve Fish Passage at Existing Projects.
When:	1996 to 1999 Implementation Schedule
How:	Using spill and improved passage, surface collectors, baffles, sluices, and with new fish friendly turbines.
Reference:	This report.

The 1995 BiOp

What:	Current Operations.
When:	1995 - ?
How:	Use spill and flow (storage) to achieve 80% FPE and use transportation.
Reference:	NMFS Biological Opinion of 1995

ing existing reservoir pools as they were designed. One of the drawdown options is dam removals. Four of the drawdown options are lowered pools with the existing dams. Three are seasonal, one is permanent. Drawdowns re-establish a partial or total permanent or temporary free-flowing Snake River between Lewiston and McNary Pool (Table 5-1). Drawdown concepts are identical to alternatives outlined in the Columbia River System Operation Review (BPA et al., 1995).

This section considers a strategy in which juvenile fish passage would be improved without reservoir drawdown. This strategy, FISHPASS, would use flow augmentation, spill, construction of surface collectors, improved spillways, and turbine runners to meet NMFS goals. The intent would be to sufficiently improve fish passage at existing hydropower projects to reduce or eliminate the need for either transportation or drawdowns. In other words, in-river migration would occur with the existing hydro system in place. We compare all these to the existing operations under the 1995 Biological Opinion of NMFS. FISHPASS can be considered the equivalent of NMFS BiOp with all criteria being achieved (FPE, survival, and TDG). It is also a *Mixed Path* option because *Transportation* would still be feasible.

Description of Existing Situation — 1995 BiOp

Most Snake River juveniles now migrate through eight hydroelectric projects, if they are not intercepted by screens and transported.

Migrating spring chinook can pass the dams via four routes: (1) the spillway (if open); (2) the turbine passage (if generating); (3) a special juvenile bypass system (if they encounter a turbine screen); and (4) a sluice or other experimental device (if one is located at the dam).

Each specific passage route for juvenile fish has risks. Turbines injure by rapid pressure changes, fish striking the wicket gates or the turbine blades, fish getting wedged between moving parts of the turbine, violent hydraulic patterns within the turbine scroll case, and other factors (Corps of Engineers, 1995b). Turbine mortality is believed to be the single largest source of juvenile mortality at the dams. The Corps suggests six percent as an average mortality. Other studies support higher and lower numbers. The Corps also estimates acute mortality of one percent in the JBS. NMFS (1995 BiOp) estimates up to three percent acute mortality via spillways. Turbine screens intercept 30 to 80 percent of the juveniles and divert them to the JBS.

Turbine mortality and forebay delay are two reasons spillways are suggested as a better fish

passage route. NMFS BiOp (1995) goal of achieving 95 percent survival of juvenile fish at each hydroelectric project requires as much as 80 percent of the river flow to be passed over spillways. NMFS currently cannot meet FPE goals of 80 percent without exceeding gas supersaturation levels that may harm or kill fish. Thus, although the BiOp recommends spill to avoid turbine problems, this is like going from the frying pan into the fire. Until more benign methods to spill or bypass fish are developed, it is not possible to achieve NMFS FPE (80 percent) or survival (95 percent) goals at all projects.

The Dalles and Bonneville powerhouses have ice/trash sluiceways which can be used as passage routes for juveniles. Ice Harbor's sluiceway recently closed but could be re-modified. Located at the powerhouse, sluiceways have been especially effective at bypassing juvenile fish and routing them away from project turbines.

Using a simple spreadsheet model (Table 5-2) and survival data from NMFS (1996) and the Corps, we estimated the potential for improving the survival of yearling spring chinook salmon smolts from the upper end of Lower Granite Reservoir to below Bonneville Dam. With existing conditions, we estimate survival to Bonneville tailrace at about 43 percent (Table 5-2). The estimate of a 10 percent per project loss (90 percent) (survival) approximates CRiSP Model results.

Table 5-2: Juvenile Survival Rates with System Improvements at Eight Dams

FPE	Survival: Project	Survival: System
Existing Screens		
50%	90%	43%
Ext Length Screens		
60%	91%	47%
70%	92%	51%
75%	93%	56%
Surface Collection		
80%	94%	61%
85%	95%	66%
90%	96%	72%

From these data, we can estimate juvenile fish survival improvements among several *In-River* paths. Table 5-2 shows that with each one percent incremental improvement project survival (for all eight dams), there is a net system survival improvement of about four to

five percent. The incremental improvements can (theoretically) come from a variety of sources including extended screens, surface collectors, and baffles which divert more fish away from turbines and may shorten travel time. Advanced turbine design could reduce project mortality by one or two percent. Reduction in TDG could also improve survival (CRiSP estimates up to three percent).

Scheduled Improvements

The Corps of Engineers is implementing fish passage improvements to increase in-river survival (Table 5-3). These improvements could improve average project survival from 90 to 93 percent thereby increasing juvenile survival to Bonneville tailrace from 0.43 to 0.56 (Table 5-2).

Table 5-3: Corps Juvenile Survival Improvement Program

Name:	Extended Length Barrier Screens (ESBS)
What:	40-foot long, Extended Submerged Barrier Screen
Where:	LGR, LGO, MCN
Fish Benefit:	10-15% FGE; 1-1.5% increased survival
Name:	Juvenile Bypass System (JBS) Improvements
What:	Improved hydraulic fish channels or handling facilities
Where:	LGR (improved), IHR (new)
Fish Benefit:	Less than 1%
Name:	Flip Lips
What:	Hydraulic improvements to spillways to reduce gas supersaturation
Where:	John Day, IHR
Fish Benefit:	Up to 3 percent? (unproven)
Name:	Surface Collector
What:	Slotted box at Powerhouse to pass/capture juveniles
Where:	Lower Granite, Bonneville
Fish Benefit:	FGE improvement 10-30 percentage points; 1-3% improved survival
Name:	Baffled Spillway
What:	Surface bypass at spillbay
Where:	The Dalles
Fish Benefit:	FPE improvement 5-20% per spillbay

Goals and Benefits of Fixing the Dams

Improvements to individual components of the hydroelectric system could be combined into many alternatives for system improvement; these are represented by the seven *In-River* alternatives (Table 5-1). Specific fish passage benefits are identified with each protocol improvement to the hydroelectric system as follows.

GOAL 1: Reduce Fish Mortality and Injury Through Turbines

Mortality estimates attributable to turbines are variable. The CRiSP Model uses seven percent (BPA et al., 1995); the Walla Walla District uses six percent; and NMFS and UW (1996) found that yearling chinook salmon mortality through the turbines at other projects range from about seven to 18 percent. We use 10 percent in our spreadsheet analysis (Table 5-2).

Several utilities along the mid-Columbia River are replacing Kaplan turbine runners (blades) with "fish-friendly" runners, and are also making changes to other intake components (e.g., wicket gates). The objective of these improvements is to reduce turbine mortality by one to two percent (Corps 1995b). Turbine runner replacements for Corps projects on the lower Snake and Columbia River could potentially achieve the same result.

GOAL 2: Reduce Fish Mortality and Injury from Spillway Passage

Juvenile fish mortality from spillway passage is estimated to be three percent maximum. Estimates range as high as ten percent during high spill (The Dalles, 1995) and as low as zero. Baffles may improve juvenile survival by some unknown amount. This might come from: (1) reduced delay in forebays; (2) reduced turbine passage; and (3) reduced JBS encounters. PIT-tag data, SARs, and balloon tag data would help quantify benefits.

GOAL 3: Increase the Effectiveness of Fish Passage Systems

Submersible screens installed in turbine intakes of most hydroelectric projects on the lower Snake River and lower Columbia River (Table 5-3) typically guide 40 to 70 percent of yearling salmon smolts and about 30 to 50 percent of sub-yearling smolts away from turbines. Unguided fish pass through project turbines, where the mortality rate is higher. If we accept five percent dam mortality (mortality from turbines) and about five percent reservoir mortality as reasonable averages, the net 10 percent mortality per project indicates that with 20 years of screen JBS technology, we have reduced juvenile mortality five

percent per project. If all fish went through the turbines, total project loss would be ten percent plus five percent (15 percent).

Although screen technology is constantly improving, it is possible that different surface oriented fish passage systems at Snake and Columbia River dams could perform better than existing submersible screen systems. If surface collectors can achieve 80 percent FPE using between 5 to 10 percent of the river flow, effective surface collection and bypass systems could reduce per-project mortality about three percent at dams with an STS. Benefits could be as high as nine percent where no screens exist (The Dalles). Additionally, surface collectors may reduce juvenile migration delay.

GOAL 4: Reduce Fish Migration Delays at Dams

Juvenile salmon typically delay their migration as they approach existing dams during daylight hours. Most juveniles pass projects after dark. Delays expose fish to additional predation and may cause impacts related to timing of ocean entry.

Drawdown of reservoirs to "natural river" level, improved fish bypass facilities (surface collection), and/or surface spill would be most likely to reduce fish migration delays at the dams. The potential fish passage benefits associated with drawdowns are listed with each specific option.

GOAL 5: Improve Juvenile Salmon Survival Through Reservoirs

The relationships between water particle travel time, smolt migration time, and juvenile fish survival have been debated without resolution (BPA et al., 1995, Harza Northwest 1994). Potential benefits to salmon migration provided by reduced travel time include: unknown but possible physiological benefits, less exposure to predators, broader and more appropriately timed ocean entry.

Reservoir drawdowns to natural river level, and/or flow augmentation from storage are the two tools that can help meet this objective. Flow augmentation is now at 10 to 12 MAF for both Snake and Columbia spring/summer flows to meet 1995 BiOp goals (spring, 85 kcfs and 220 kcfs; summer, 55 kcfs and 160 kcfs). Using storage to improve smolt survival with dams in place has probably reached the point of diminishing returns.

Thirty-five foot drawdowns would, at best, improve smolt survival an estimated one to two percent per project (Table 5-3). For these partial drawdown alternatives, there would still be smolt mortality from turbines, fish bypass systems, spill and (smaller) reservoirs. It

is possible that net benefits could even be negative if new fish passage facilities are not as good as existing facilities.

Drawdown to natural river level would result in virtual elimination of smolt mortality related to the projects or about ten percent per project. This assumes that all mortality attributed to hydroelectric projects would be eliminated. Some "natural" river mortality would remain and that amount is probably about one to two percent per project reach.

Goal 6: Increase Mainstem River Habitat by Reservoir Drawdown

Existing reservoirs on the lower Snake River and Columbia River eliminated 330 miles of mainstem river habitat historically available to spawning adults, rearing juveniles, or both. The Independent Scientific Advisory Board (ISRB) has reviewed historic spawning and juvenile production areas and found that the Lower Snake corridor contains significant salmon production areas now inundated by dams. Permanent reservoir drawdown would increase the length of river for salmon, possibly increasing smolt production because chinook and steelhead are adapted to spawning, rearing, and migrating in rivers, not reservoirs.

Existing reservoirs do provide rearing habitat for salmon, particularly fall chinook. Thus, reservoir drawdown may generate more limited benefits for some stocks or life history stages of salmon. Conceivably, it could even decrease overall production of fall chinook (BPA et al., 1995).

The potential survival benefits from reservoir drawdown were covered above. The potential for increased numbers of smolts (in addition to increased survival) is uncertain enough that additional production benefits have not been estimated.

Goal 7: Reduce Gas Supersaturation Caused by Spills

Considerable effort has been focused on how to reduce gas supersaturation caused by spillway releases. The objective of these potential improvements (see below) would be to eliminate the "Catch 22" situation where sufficient spill to achieve 80 percent FPE goals (NMFS 1995) cannot be released due to TDG violations and potential lethal effects of gas supersaturation on fish.

Spillway discharges up to 80 percent of river flow were recommended by NMFS (1995) to achieve 95 percent fish passage survival at lower Snake and Columbia River projects. However, "spill caps" to control gas supersaturation have held spill levels substantially below NMFS recommendations.

Modified spillways can reduce but will not eliminate gas supersaturation associated with large spills. The Dalles spillway can discharge about 65 percent of river flow within recommended gas supersaturation criteria (120%). Unfortunately, high spill may cause mortality for different reasons (hydraulic injury, predation) as observed in 1995 (10 percent mortality estimate from radio-tagged fish research conducted by Dr. Carl Schreck, pers. comm., USACE). Because of its shallow design, it may be more biologic and cost effective to use spill at The Dalles compared to other less effective and more costly methods of improved fish bypass.

Modification of spillways to allow discharge levels near NMFS (1995) recommendations could improve overall smolt survival at each project by one to three percent over existing levels. This improvement would result from more water and fish being spilled, rather than requiring most of the water (and fish) to enter turbine intakes due to "spill caps." In 1996, flip lips at Wanapum Dam may have reduced gas but elevated juvenile mortality from other causes.

The Drawdown Options

In addition to modifying the existing dams, the *In-River Path* includes two natural river drawdown alternatives and three partial reservoir drawdown concepts. These alternatives are further described below.

Seasonal Natural River Operation

This option is 100-foot drawdowns at two or four lower Snake River projects to natural river level from mid-April through August. This concept includes flow augmentation, shifts in the flood control system, and other measures outlined in the SOR.

Dam removal will increase smolt survival 10 percent per project in the lower Snake River. The average survival of smolts from Lower Granite reservoir to Bonneville tailwater should therefore increase from 43 percent (Table 5-2) to 66 percent (Table 5-4) for this natural river alternative. Pool fluctuation would have a variety of biologic impacts of uncertain and dubious value. Construction would take 15 years and would require technical engineering that has never been tried.

Permanent Natural River Operation

The Permanent Natural River alternative would permanently re-establish the Snake River to its historical level between Lewiston, Idaho, and the McNary pool. The embankment sections of the dams at the four lower Snake projects would be removed to allow unrestricted natural migration. The concrete sections, powerhouses, and spillways of each project would be protected from high flows and "mothballed" for permanent shutdown including equipment removal.

Fish passage benefits of this alternative would be a smolt survival increase of 10 percent per project in the lower Snake River, due to removal of hydroelectric facilities and obstructions during the smolt migration period. Overall smolt survival is estimated to be 66 percent for a four dam removal and 53 percent for a two dam removal, respectively (Section 7). With further enhanced FGE and survival improvements of 3% to Lower Columbia dams, juvenile system survival under a four dam removal scenario could be increased to as much as 75 percent. In addition, adult salmon passage would be improved an estimated 13 percent by removal of migration obstacles. The estimate is based on inter-dam adult losses of three percent (Bevan et al., 1994). Unlike seasonal drawdown, natural river habitat would eventually be restored. The implementation time of three to five years would exceed all other options except status quo (BiOp).

Table 5-4: Juvenile In-River Survival Rates with Dam Removals

Fish Passage Efficiency	Each Project	System - 4 Dams	System - 6 Dams
Existing Screens			
50%	90%	66%	53%
Extended Screens			
60%	91%	69%	57%
70%	92%	72%	61%
Surface Collectors			
80%	93%	75%	65%

Partial and Seasonal Drawdown

Drawdowns of the four lower Snake River reservoirs to 35 feet below normal pool would begin in April and end in August. Substantial changes to the existing projects would be required to allow fish passage during the drawdown/refill periods and at the lower pool levels. The changes would require substantial engineering and construction, and take 12

to 15 years to implement (Corps, 1994). This concept includes flow augmentation, shifts in the flood control system, and other measures outlined in the SOR.

Juvenile fish passage benefits of this alternative, with optimistic assumptions, would be a two to three percent increase in smolt survival at each Snake River project. However, modified fish passage systems (submersible screens) will entail risks, even with expensive modifications. The overall survival of smolts from Lower Granite Reservoir to below Bonneville Dam is estimated to be about 56 percent for this alternative (Table 5-2). This would be a 30 percent increase compared to existing 1995 in-river conditions. It would have similar benefits to FISHPASS (see below).

Partial and Seasonal Drawdown of Only Lower Granite

This alternative is identical to the previous option but only draws one pool, Lower Granite Reservoir, 35-feet below normal pool. This drawdown would be done from mid-April through August of each year to accelerate juvenile salmon downstream migration. Unlike the four-pool option, this option is much simpler and less costly because the tailwater problems are eliminated. This alternative may increase juvenile survival by two percent with an implementation time of three years. The expected overall population improvement would be statistically difficult to distinguish from the existing 1995 condition.

Detailed Fishery Operating Plan (DFOP)

This plan would improve juvenile fish survival using flow targets at specific projects, increased spill, and 35-foot drawdowns of the four lower Snake River reservoirs on a seasonal basis. Most of the anticipated benefits occur from expediting migration, not from improved passage. Benefits are impossible to prove without exercising the option. Under this alternative, transportation of juvenile salmon would be eliminated.

Increases in juvenile salmon survival for this concept would be similar to those described for the partial and seasonal drawdowns, with an additional survival benefit added by flow augmentation and increased spill in the lower Columbia River. There are no "proven" estimates for enhanced flow augmentation benefits. Modeled benefits are discussed in Section 10, Risks and Uncertainties. Accepting a three percent benefit at each project would lead to an overall level of smolt survival from Lower Granite Reservoir to below Bonneville Dam at about 56 percent, with overall conditions similar to Table 5-2. Because benefits are uncertain, this option has a high risk. Its annual cost exceeds project removal (Section 8, Costs and Economic Trade-Offs).

Improve Fish Passage at Existing Projects (FISHPASS)

The intent of this alternative would be to improve fish passage facilities at existing hydroelectric projects sufficiently that transportation and/or drawdown of any depth would not be needed for recovery of endangered salmon stocks. This concept was not included in the SOR.

Fish passage technology is not sufficiently mature to predict the increase in survival possible for all potential improvements. Recent advancements in fish passage have been made in the areas of turbine improvements that could reduce fish mortality (Corps, 1995b), surface bypass concepts that would improve fish guidance around turbines (Harza Northwest, 1995a and 1995b), and spillway improvements to reduce gas supersaturation (Corps, 1996b). Application of these and other technologies to the lower Snake River and lower Columbia River could increase survival of endangered salmon stocks but with risks and uncertain implementation schedules to meet criteria.

Fish passage improvements included in this alternative include the following:

- Install surface bypass facilities at all projects to supplement or replace submersible screen systems. Surface bypass systems (with or without turbine screens) were assumed but not proven to be capable of intercepting and safely bypassing at least 80 percent of yearling salmon and 50 percent of sub-yearling salmon (Harza Northwest, 1995a and 1995b).
- Reconstruct or replace turbine runners to increase fish survival (Corps, 1995b). This may increase salmon survival one to two percent for fish passing through turbines.
- Modify spillways to reduce gas supersaturation in the tailrace while maintaining high juvenile passage and survival rates. These measures could include structural modifications within the tailrace (e.g., flip lips) or spillway baffles to reduce water volume required for fish passage.

The major changes outlined above would be complemented with 1995 BiOp flow augmentation and installation of additional extended submersible barrier screens at some projects.

Taken together, the system improvements within this alternative could result in a smolt survival rate of 56 percent from Lower Granite Reservoir to below Bonneville Dam. This would be a 30 percent improvement over existing conditions with respect to juvenile salmon survival.

Summary of the In-River Path

We review seven possible alternative sub-paths for the *In-River Path* (Table 5-5). These include the existing system (1995 BiOp) with high spill and flow augmentation; two natural river drawdowns; three partial and seasonal drawdowns; and a normal pool operation with state-of-the-art surface bypass.

Non-drawdown alternatives can maximally improve juvenile survival by 30 percent in the system. Risks, time frames, and costs to meet goals are difficult to quantify. No adult benefits are achieved. To obtain greater fish benefits will require drawdowns.

Permanent Natural River (100-foot) drawdowns of four Snake River dams will improve salmon survival by about 72 percent above the existing (1995) conditions. This type of drawdown will likely create or eventually renew fall chinook spawning habitat. It may reduce fall chinook rearing habitat. It will decrease travel time to the estuary for spring chinook by about seven days (Harza, 1994). It will eventually restore physical, but not total hydraulic habitat due to upstream storage. It would convey the largest benefit to salmon of all other In-River options. Terrestrial and biotic impacts in the lower Snake would be restored by natural processes in time. Sediments would be re-distributed and presumably find their way eventually to the McNary Pool.

Seasonal natural river drawdowns will remove many causes of juvenile mortality to migrating smolts. However, pool fluctuation is likely to be biologically devastating to many organisms in or adjacent to the reservoirs and possibly even migrating smolts too because of food chain disruptions from cyclic inundation and desiccation. Implementation time of 16 years is also viewed as biologically unattractive. It would also have significant recreational impacts due to a variable pool.

Partial drawdowns provide limited benefits (unproven but estimated three to 16 percent benefit) to salmon. Smolt migration rates would improve slightly. However, risks of increased mortality at dams and the relatively high costs and long implementation times make partial seasonal drawdowns unattractive. Seasonal partial drawdowns are biologically risky because of the cyclic nature of inundation and desiccation which will disrupt aquatic and terrestrial communities. It would also have significant recreational impacts due to a variable pool.

Significant modification of the existing system using surface collectors, baffled spill, gas reduction, and flow augmentation was also examined (FISHPASS). This option uses technology to achieve the goals established in the BiOp by NMFS. It provides maximum benefits of about three percent increased juvenile survival per project. Juvenile survival

Table 5-5: Comparison of Seven In-River Sub-Paths

	Name	Description	Flow/Spill	Fish Benefit	Biological Risk	Implementation
1	**Existing 1995 BiOp**	80% FPE	High/High a = 0%	j = 10-20%	Mod-Low	Immediate
2	**(2-4) 100-ft Permanent Drawdown**	Full restoration of Snake	n/a a = 10-20%	j = 30-72%	Low	5 years
3	**(2-4) 100-ft Seasonal Drawdown**	Temporary Migration Only Restoration	n/a	j = 30-60% a = 10-20%	High	16 years
4	**(4) 35-ft Seasonal Drawdown**	Hydraulic Improvement	High/High a = 0%	j = 12%	Very High	13 years
5	**Seasonal Drawdown LGR**	Limited Hydraulic Improvement	High/High a = 0%	j = 3%	Moderate	2-3 years
6	**(4) 35-ft + Flow Drawdowns** (DFOP)	Hydraulic Improvement	Very High/High a = 0%	j = 12-16%	High	13 years
7	**FISHPASS**	80% FPE	Mod/Mod a = 0%	j = 30% incremental improvement	Mod-Low	8-10 years

j = juvenile
a = adult
n/a = not applicable

from Lower Granite to Bonneville tailwater would optimally increase about 30 percent to 56 percent. Compared to other in-river options, FISHPASS provides more benefit and less risk than Partial or Seasonal Drawdowns. FISHPASS provides considerably less fish benefits than Permanent Natural River Drawdowns and takes longer to implement.

Based on overall risks vs. potential benefits, the biologically best alternative option is Permanent Natural River followed by FISHPASS, then existing 1995 BiOp. Only Permanent Natural River helps adults. We do not recommend seasonal or partial drawdowns. Seasonal Drawdowns will have highly undesired biological impacts. They take substantial engineering and schedules to implement. Partial Drawdowns don't do enough for fish, have high risks, or take too long to implement.

Section 6

DECISION 1996

Section 6 DECISION 1996

The National Marine Fishery Service Biological Opinion (1995) suggests that it will make final decisions about whether to recommend Reservoir Drawdowns or build surface collectors at Snake and Lower Columbia river dams in 1999 after three more years of survival data are collected. Others point out that similar studies have been conducted since 1968 and we have sufficient data now to make decisions (Mundy et al., 1994). Because many sub-populations are already extirpated and those that remain are depressed and declining, further delay may make matters worse (Bevan et al., 1994, Table 3-4). The Tribal Plan calls for immediate action including use of Drawdowns on the Lower Snake and John Day dams with surface collectors at the remaining Lower Columbia dams.

The following section discusses the benefits and liabilities of making major path decisions in 1996 versus waiting until 1999. The three major paths are *Transportation*, *In-River*, or use of both, which we call the *Mixed Path*.

Transportation Path

The *Transportation Path* uses a combination of barges and trucks to transport juvenile salmonids collected at up-river hydroelectric projects to below Bonneville Dam. The two reasons for transportation are: (1) to eliminate juvenile mortality at the dams and in the reservoirs, and (2) to decrease juvenile travel time to the estuary. Data collected by NMFS shows that adult return rates are higher for transported groups in 12 out of 17 years compared to "control" fish left in the river (Park, 1993; In Bevan et al., 1994).

Current reach survival estimates for spring chinook indicate that only about 50 to 70 percent of those juveniles which enter the Lower Granite reservoir survive to McNary Dam. Results from juvenile survival models (CRiSP and FLUSH) predict that between 25 and 45 percent of migrants that enter Lower Granite reservoir survive to below

Bonneville Dam (Anderson, 1996c). Current CRiSP modeling data (Anderson, 1996b) predict that transport survival to below Bonneville Dam ranges from 88 to 95 percent or approximately twice that of the most optimistic estimate of in-river survival. Transportation also shortens current in-river migration time frames (20 to 50 days) to about two days.

Although transportation produces more adults than in-river migration, it may not prevent extinction. For this reason, some agencies and tribes (e.g., CRiTFC, 1995) suggest that improving hydroelectric operations to increase in-river migration conditions is a better strategy to reverse salmon declines. We provide a discussion of the arguments for and against the *Transportation Path*.

The Argument for the Transportation Path

Researchers from the NMFS have been conducting studies on the transportation program for more than 25 years. The results of these transportation studies are summarized in the NMFS 1995 Biological Opinion (BiOp) which states:

> *From 1968 through 1980, 24 separate truck and barge transportation studies were conducted on juvenile spring/summer chinook at various dams on the Snake River. In ten of the tests (42 percent), significantly more transported fish were recovered as adults than control fish, indicating higher survival for the transported group. In only one test (four percent), significantly more control fish were recovered than transported fish. In 13 tests (54 percent), adult recoveries were too few to identify statistical difference between transported and control fish.*

The NMFS analysis states that the transport-to-control ratio (T/C) for these 24 studies has ranged from 0.7 to 18.1, with only three of these studies reporting T/C ratios of less than one. This means that of the 24 studies, 21 showed transported juveniles produced more returning adults than in-river migrants. The NMFS also report positive T/C ratios for spring/summer chinook, sockeye, fall chinook and steelhead in other transportation experiments. Additionally, no evidence of adult homing impairment or straying has been observed in any of the transport studies.

The National Research Council (NRC) and the Salmon Recovery Team (SRT) support the NMFS conclusion that transportation is the current best means to protect downstream juvenile migrants with one caveat: that additional information is needed on adult homing, return rate, and delayed juvenile mortality before transportation can be considered as a long-term solution for the mainstem passage problem.

The Argument Against the Transportation Path

Mundy et al., (1994) reviewed the results of the transportation studies conducted to date and concluded they are seriously flawed and are not representative of the general populations response to transport. The arguments against the *Transportation Path* are presented in detail by an Ad Hoc Transportation Review Group 1992, and Mundy et al., 1994. In general, the major points of contention with the transportation studies include:

1. Experimental Procedures. Control groups were not true controls. They were often trucked to release sites. Transportation studies are thus a comparison of short-haul versus long-haul transportation rather than transport versus in-river migration. Additionally, the combined stress of fish handling and tagging followed by immediate trucking of the controls may have lead to artificially high mortalities for the in-river (control) groups.
2. Some control fish were actually transported at downstream collector facilities which biased study results in favor of transported fish.
3. Evaluations did not assess the performance of hatchery and wild fish separately. There is the possibility that wild fish respond negatively to transportation and hatchery fish, positively, or vice-versa. Data collected from 1994 migrants reaffirms this hypothesis (Figure 11-3).
4. Evaluations were not designed to assess adult return rates to spawning grounds. The T/C ratios were generally measured to the release point not the spawning ground. A subset of data show that T/C ratios were lower at the spawning grounds indicating either a homing problem or excessive mortality on transport fish prior to arrival in natal streams.
5. Transportation evaluations have been conducted under river conditions favoring power production rather than smolt passage. Thus, controls (in-river) incurred higher mortalities which inflated T/C ratios.
6. Even if transportation returns more adults than in-river migrants, the overall adult return rate observed for transported fish is insufficient to recover these stocks.

The first four points are criticisms of experimental methods. The fifth point is a value judgment. The hydropower system has been operated principally to maximize power and reduce flooding (eliminate spill) until 1994. Spill and high spring flows may be highly beneficial to in-river migrants. The ad hoc committee recommends tests of high spills and flows with further evaluation of costs and benefits against less expensive transportation.

The sixth and final point is the source of dissatisfaction; fish are going extinct and transportation is not the "cure-all" for the problem.

Each of these points can and should be addressed with better experimental design using PIT tags. The NMFS, NRC, and the SRT endorse such a study program. New studies now in progress will evaluate each of the seven criticisms (Section 11).

Five Reasons to Select the Transportation Path

The rationale for selecting the *Transportation Path* as the preferred path now and without further study is based on five arguments:

1. ***Transportation* Maximizes Juvenile Survival.** Current CRiSP estimates of juvenile survival indicate that only about 40 to 50 percent of the juveniles passing at Lower Granite dam and migrating in-river survive to below Bonneville Dam. In comparison, transport survival to this same point is estimated at 80 to 100 percent. If a one percent increase in juvenile survival equates to a one percent gain in adult survival, then the transportation path should produce, as most studies have confirmed, twice as many adults as the *In-River Path.*

2. ***Transportation* Minimizes Juvenile Travel Time to the Estuary.** Transported fish are released below Bonneville Dam within two days of being collected at one of the four juvenile collection facilities. In-river fish take anywhere from 20 to 50 days to migrate through all eight mainstem projects. Such an increase in travel time increases juvenile losses due to predation and may result in decreased fitness to survive the transition from fresh to salt water.

3. ***Transportation* is the Least Cost Alternative Compared to All Other Paths.** In fact, if the region were to fully implement this option, fish mitigation costs would be reduced by $200 million annually (Section 8, Costs). These savings could then be used for other salmon saving measures such as the screening of irrigation diversions, protection and improvement of rearing habitat, wetland restoration, or even purchasing entire watersheds for use as salmon sanctuaries.

4. **Scientifically, *Transportation* has been Shown to Produce More Adults.** The region has been evaluating the transportation program for over 25 years. The results of these evaluations have shown that transported juveniles produce significantly more adults than juveniles allowed to migrate in-river. These data have been reviewed by scientists from the NMFS, SRT, and the NRC. Based on their review of the data, all three

groups chose the *Transportation Path* as the tool of choice at present for mitigating hydroelectric impacts on downstream juvenile migrants.

5. **Lack of a Better Alternative.** Many scientists in the region have suggested that reservoir drawdown or complete removal of all Snake River dams will work best for recovering Snake River fish stocks. Unfortunately, even with dam removal, Snake River fish still must bypass four Columbia River projects in order to reach the estuary. We have estimated that juvenile survival under this scenario will increase from its current base level of 43 percent to approximately 66 percent. This 66 percent survival rate is still 14 percentage points lower than the lowest CRiSP survival estimate for transported juveniles (80 percent).

Risks of Selecting the Transportation Path

Although the five arguments for selecting the *Transportation Path* are legitimate, there remains three concerns about *Transportation.*

1. **Unknown SARs for Transported Wild Juveniles.** To date, the information we have on the Smolt-to-Adult return (SAR) rates for transported wild juveniles have been based on estimates and not precise measurements. Therefore, it is not known whether or not the adult return rate from transported juveniles is either accurate or sufficient to maintain wild populations.

2. **Delayed Juvenile Mortality.** There is still some debate as to the level of delayed mortality occurring on transported juveniles. FLUSH model results indicate that delayed mortality for transported juveniles may be as high as 50 percent while the CRiSP model estimates this loss at only five to 20 percent.

3. **Adult Homing.** The T/C ratios at the spawning grounds or hatcheries are not the same as seen at Lower Granite Dam. One explanation for this discrepancy is that transported adults die in greater numbers than in-river fish after passing Lower Granite but before spawning. Past data were statistically inadequate to answer this question. If more adult PIT-tag detectors are installed, future data could answer the question for hatchery fish. We will not get much data on wild fish, but some evidence will occur on losses between Bonneville and Lower Granite dams. If homing instinct is weaker in transported fish, this could explain the difference. New PIT-tag data to be collected from 1996 to 1999 (Section 11) should be sufficient to re-evaluate this question. If adult homing and not juvenile survival is the problem, then an in-river solution may be required.

The In-River Path

The *In-River Path* is any modification of the mainstem salmon migratory corridor that enhances the survival of any life history stage of target species that utilize the corridor. We have identified in Table 2-1 potential operational and structural changes. The Independent Scientific Review Group reported in May 1996 to the Northwest Power Planning Council that recovery of natural salmon populations will require creation of a more "normative" river. The NMFS in their 1995 BiOp defined recovery as: "... improvement in the status of a species and the ecosystem upon which they depend. Said another way, recovery is the process by which species' ecosystems are restored so [they] can support self-sustaining and self regulating populations of listed species as persistent members of native biotic communities."

Arguments for the In-River Path

There are legitimate reasons why the *In-River Path* could be selected in 1996 without further data collection. The following seven reasons capture the rationale:

1. Salmon survival through the hydro system is maximized under the Drawdown Sub-Path which increases in-river salmon survival between 30 and 72 percent above current levels.

2. Dam removal, the most extreme in-river path, could re-establish between 70 and 140 miles of Snake River habitat. The restoration of this habitat will not only remove mortality from dams and reservoirs, it will increase migration rate, provide new spawning and rearing habitat for salmon and other native fish and wildlife. The only question we need to answer is whether we value these 140 miles of free flowing river more than the economic value of the hydro system.

3. Transportation and hatcheries have been used to mitigate for hydroelectric project losses since 1968. They have failed to adequately protect salmon and steelhead populations as evidenced by actual or imminent extinctions of many Snake River sub-populations (CRITFC, 1995). Even hatchery populations are headed for extinction. It is time to give natural processes a chance since artificial means appear to have failed.

4. Transportation has always been considered a temporary measure until more adequate (i.e., in-river) improvements could be designed and implemented. Twenty five years

is more than temporary. Spill together with flow augmentation is the interim "In-river" Path (NMFS, 1995) until further technical improvements can be designed, tested and implemented at the dams in the next several years.

5. Transportation has a variety of unknown impacts and potential selectively deleterious consequences of which we know little and have little chance of understanding in the near term. Some of these include time shifts in migration to the estuary and ocean; delayed mortality due to screens; crowding and handling; and homing impairment of transported adults (Bevan et al., 1994). It is unlikely that we will resolve any of these questions with three more years of data. Even less is known of the interaction of hatchery and wild fish, although numerous concerns exist over competition, introgression, loss of genetic diversity and fitness.

6. Transportation concentrates wild and hatchery fish together. This unnatural environment creates stress and competition and may exacerbate juvenile mortality.

7. Transportation is used to preclude more costly but potentially effective changes at the dams that will improve the in-river Path. These include improved spill, reduced gas (TDG), higher FPE, lower mortality at the concrete, and faster passage across the forebay via surface collectors.

Arguments Against the In-River Path

There are five arguments against the selection of the *In-River Path* in 1996.

1. Transportation has been shown to return more adults to Lower Granite Dam than in-river migration consistently during the entire history of mark-recapture studies (Bevan et al., 1994). We should not abandon transportation until we are certain that in-river migration can return similar numbers of adults.

2. In-river migration may in fact be similar or better than transportation, however the data are not yet conclusive. More conclusive data is expected by 1999. Until then, the NMFS protocol, endorsed by the National Research Council (1996), is to transport unmarked fish while testing in-river survival of marked fish under improved river conditions (increased spill and flow).

3. If 1996-99 tests of prototype facilities such as baffles, surface collectors, flip lips and guidance curtains are successful in improving in-river passage conditions, actual in-

river performance (adult returns) will improve and likely be more competitive with transportation when these facilities are implemented. If *In-River* is selected now, especially the options with dams still in place and new facility performance is poor, it could increase the risk of extinction of more sub-populations. Poor performance could also lead decision makers to simply abandon the *In-River Path* in 1999 before it has a chance to succeed.

4. A strategy that returns the greatest number of adults may be one that utilizes both *In-River* and *Transportation* paths. For example, *Transportation* may be a better strategy under low flow and high temperatures (summer season or during drought years), while *In-River* may return more adults during high flow. Abandoning the *Transportation Path* as a potential tool until proven that it has no value is premature.

5. The economic loss and irrevocable decision of dam removal is simply not worth the value of a restored river and the increase in fish and wildlife populations, regardless of how successful. Other less costly measures may prevent extinction. Hydropower is only one of many problems plaguing salmon. Hence even dam removal comes with no money-back guarantee.

Three Reasons for Selecting the In-River Path

There are three major reasons for selecting the *In-River Path* in 1996. These are:

1. The *In-River Drawdown Sub-Path* maximizes survival through the hydroelectric system. The four pool drawdown option increases salmon survival by 72 percent.

2. Dam removal will re-establish, in time, a riverine ecosystem. The dam removal alternative restores between 70 (two-pool) and 140 (four-pool) miles of mainstem Snake River salmonid habitat. The restoration of this habitat will improve both juvenile and adult survival, increase migration rate, and provide new spawning, rearing, and wildlife habitat.

3. The *In-River Path* is the only path that meets recovery objectives. It is the sole path that addresses the key elemental changes necessary for improving salmon ecosystems: better and more plentiful habitat, re-establishment of natural processes, and reduced human impacts.

Risks of Selecting the In-River Path

The primary risk associated with selecting the *In-River Path* at this time is the unknown juvenile survival rate for the *Transportation Path.* If survival under the *Transportation Path* is high (say 80 percent) then this exceeds the survival rate for all *In-River* sub paths with the exception of the Four Pool Dam Removal with Columbia River improvements (96 percent). The absolute difference in costs between these two paths is approximately $350 million annually.

The Mixed Path

The *Mixed Path* reflects the current mode of hydro system operation for protecting Snake River stocks. A combination of juvenile transportation and natural in-river migration is used to deliver juvenile migrants to below Bonneville Dam. The percentage of juveniles transported is dependent on Snake River discharge. According to the NMFS 1195 BiOp, this *Mixed Path* approach results in approximately 74 percent of the spring chinook juveniles arriving at Lower Granite Dam being transported at flows over 85 kcfs and 56 percent being transported at flows over 100 kcfs. Juveniles can be transported at four locations: Lower Granite, Little Goose, Lower Monumental, and McNary dams. Favorable in-river migration conditions are currently established through the use of a combination of tools including controlled spill, screens, extended screens, gas abatement structures, and flow augmentation.

The Argument for the Mixed Path

The *Mixed Path* is the culmination of over 25 years of fish passage research and development. This experience has provided us with a good understanding of both the natural and structural conditions needed to protect juvenile and adult salmonids. The cost of this experience has been estimated at over one billion dollars.

Our 25 years of experience has also taught us that we will never really know, or be able to measure, all of the factors that affect salmon survival. Thus, any attempt to select a single cost-effective strategy to save these stocks will fail. What is needed is an approach that "Spreads-The-Risk" between what is and isn't known about the effects our mitigation tools have on salmonid survival and reproductive success.

The *Mixed Path* achieves the "Spread-the-Risk" philosophy by using a combination of tools to protect anadromous salmonid stocks. This strategy uses flow augmentation to maintain adequate river temperatures and decrease juvenile travel time to the estuary; spill and screens to increase juvenile survival past dams; and transportation to remove juveniles from the system when riverine conditions become unfavorable (high gas, water temperature etc.).

The flexibility of the *Mixed Path* is its single greatest asset. River conditions can change dramatically even in a single day. For example, turbine outages, lack of power demand or high runoff can each force spill to occur at the projects which may raise TDG levels to lethal levels. A system which relies solely on an in-river strategy under these conditions could periodically destroy the annual juvenile migration and subsequent adult returns.

Relying solely on a transportation strategy also has its risks. For example, staff from the NMFS, SRT, and NRC have all reviewed the results of the transportation research and have all concluded that additional information on adult homing impairment, genetic effects, and adult return rates are needed before transportation can be considered as a long-term solution for the mainstem passage problem. Thus, if the perceived problems with transportation are indeed real, relying solely on this path to recover these stocks will also fail.

The Argument Against the Mixed Path

The primary argument against the *Mixed Path* approach is based on the efficiency of the system. While some may see a *Mixed Path* approach as highly flexible others view it as highly inefficient. This is because the path takes a shotgun approach to solving the mainstem passage problem. For example, the selection of this path ignores past data showing that the *Transportation Path* produces twice as many adults as the *In-River Path*. It ignores the fact that data supporting the use of flow augmentation for increasing juvenile survival is equivocal, and ignores the fact that tools used to enhance the *Transportation Path* also decrease the effectiveness of the *In-River Path*. In short, every tool has value regardless of its cost or proof of biological effectiveness.

The lack of efficiency in the *Mixed Path* leads to increased costs (more tools) and reduces resources that could be made available for improving the other three Hs (Habitat, Harvest, Hatcheries). For example, the selection of the *Transportation Path* as the sole mainstem mitigation measure would reduce annual salmon expenditures by $200 million. This money

could then be used for habitat improvement projects, screening of irrigation diversions, watershed restoration, establishing salmon refugia or pollution abatement projects in river basins throughout the region. The benefits to the fish and wildlife of the region from these types of projects would be enormous in comparison to the small, or maybe non-existent, improvements in salmon survival seen in the Snake River from the implementation of the *Mixed Path*.

Four Reasons to Select the Mixed Path

The rationale for selecting the *Mixed Path* as the preferred path now and without further study is based on four arguments.

1. **Twenty-five Years of Research and System Improvement.** The region has spent over 25 years and one billion dollars testing and improving our existing system of screen, bypass and transportation programs. Recent PIT-tag studies have shown that juvenile survival through most projects exceeds 90 percent. With further improvements in system design and operation, juvenile survivals of 93 percent per project may be achievable. A 93 percent per project survival rate equates to a 56 percent system survival (eight projects). Combined with juvenile transportation survival rates estimated at 88 percent results in a combined 72 percent of the juveniles reaching the head of Lower Granite dam surviving to below Bonneville dam. This survival rate is about equal to the estimated juvenile survival for the four pool dam removal.

2. **Flexibility.** The *Mixed Path* offers the most flexibility of any of the alternatives. Under this strategy, the most efficient tool for mitigating hydro system impacts can be selected based on river condition. During drought years, transportation can be maximized to increase juvenile survival and flow augmentation can be used to help reduce river temperatures for migrating adults. In a good water year the tools of spill, increased flow, and screening systems can be used to protect in-river migrants. When river flows are high and gas supersaturation is a problem the transportation tool can be used to "Spread-the-Risk" in regards to mitigating for high TDG. All of this flexibility leads to potentially less risk of choosing the wrong path and the safest way for increasing juvenile survival and adult returns.

3. **Science.** The results of past transportation studies have shown that in some years in-river migrants produced as many or more returning adults than transported juveniles. Thus, a strategy that leaves some juveniles in-river and places others in barges each

year has a better chance of reaping the benefits and reducing the uncertainties associated with each path then a strategy that focuses only on a single solution. Also, unmeasurable benefits of natural selection may accrue to in-river wild fish that are lost when we protect fish with hatcheries and barges.

4. **Ocean Conditions.** Some researchers have argued that poor ocean conditions, not our hydropower system, is what has driven Snake River salmonid stocks to the brink of extinction. They point to declining salmon stocks in virtually every West Coast river as evidence to support this claim. Because poor ocean conditions can overwhelm any improvement we might make in the freshwater environment, they argue to "Stay-the-Course" with the existing system until ocean conditions improve. The region needs to have faith that management strategies developed over a 25 year time period will be shown to be effective if given the chance.

Risks of Selecting the Mixed Path

The major risk associated with relying on a *Mixed Path* for protecting Snake River salmon stocks is of course extinction. However, this risk is an integral part of any of the paths. Other risks associated with the *Mixed Path* include:

Inefficiency. Many of the tools used to increase the effectiveness of the *Transportation Path* may decrease the effectiveness of the *In-River Path.* This leads to increased costs and waste.

Decreased SARs. By not focusing all of our resources on a single path we risk not being able to maximize the smolt-to-adult rate (SAR) for that path. If one path consistently produces more adults than another, resources spent on the less productive path are not only wasted but also decrease the overall adult return rate to the river. Because of this, recovery goals may never be achieved or may be extended in time. Either outcome increases the chance of extinction.

Section 7

DECISION 1999

Section 7 DECISION 1999

Introduction

In the 1995 BiOp the NMFS outlined the study program for hydro system improvements and research needs as follows:

- Quantify the survival benefits of in-river versus transport.
- Determine the ability of surface collection to improve in-river survival or juvenile collection.
- Select a preferred drawdown alternative.
- Answer the delayed juvenile mortality question for transported and in-river juveniles.
- Determine the adequacy of hydro system or transportation improvements for stock recovery in the absence of drawdowns.
- Conduct improved transportation research to reexamine transport benefit issues.

The NMFS goal is to justify the selection of a preferred hydro system operation in 1999. Throughout this report we refer to this decision point as Decision 1999.

The NMFS established a logical plan to collect the data but did not establish the criteria for how new data will be interpreted or the paths implemented based on these criteria. By defining criteria and paths prior to data collection, unbiased biological analysis can be used to guide the decision process. This will add credibility, certainty, and confidence to the process. Once the best biological options are fully understood, economic and social factors can be incorporated into the selection of a preferred path.

This section develops the criteria and the hydro system operation (path) that will be implemented based on whether or not proposed criteria are met. This is accomplished utilizing a path selection process which identifies major paths, criteria for path selection,

data needed for criteria development, specific biological goals for these paths, tools to achieve these goals, and the criteria used for tool selection.

We begin with a brief discussion of the major assumptions inherent in the path selection process.

Path Assumptions

The path selection process is based on seven major assumptions. These are:

1. **A preferred hydro system operation (path) will be selected in 1999.** The 1999 target date was established in the NMFS BiOp, 1995. We have assumed that the region will select a path based on the data and analyses completed by the end of 1999 regardless of data quality or statistical certainty.

2. **Criteria apply only to spring/summer chinook.** The Smolt-to-Adult-Return rate (SAR) and Transport-to-In-River Ratio (TIR) criteria used for selecting a path pertain only to spring/summer chinook. Fall chinook populations are too low for conducting marking studies. NMFS assumes the path that maximizes spring/summer chinook survival will also maximize the survival of Snake River fall chinook.

3. **SAR criteria are considered threshold values.** The SAR values established for path selection are considered threshold values at which the need for more drastic actions should be considered. As SARs decrease our willingness to consider paths with more risks, uncertainties, costs, and shorter implementation times should increase if saving Snake River salmon is the goal. The SAR criteria presented in this report should also be considered as a place holder value until such time as population biologists working under the PATH[1] process develop a more biologically defensible value.

4. **The TIR criterion, in conjunction with juvenile reach survival estimates, is an indicator of the survival rate for transported juveniles.** In other words, the TIR measures the amount of delayed mortality occurring to transported juveniles. This also assumes that reach survival estimates accurately reflect juvenile survival through the system and that in-river migrants experience little delayed mortality after passing Bonneville Dam.

[1] Plan for Analyzing and Testing Hypothesis (PATH) sponsored by NMFS.

5. **PIT-Tag data will be used to determine if criteria are achieved.** The studies, data and analyses that will be used for quantifying the SAR and TIR criteria are presented in Section 11.

6. **The collection of more biological data will make path choices clearer.** There is considerable risk that the data collected between now and the end of 1999 will be just as controversial as the data already in hand.

7. **Habitat, hatcheries, harvest, and the ocean conditions all affect the SAR.** We acknowledge that the other Hs as well as ocean conditions affect the SARs observed for each brood year. Quantification of non-hydropower impacts are outside the scope of this document. Scientists working through the PATH process are attempting to isolate the effect each of the Hs has on salmon survival, quantify the increase in survival possible from mitigation measures, establish the time frames needed before these survival benefits accrue to the population, and quantify the overall improvement in survival needed to maintain the species. If the PATH process is successful, criteria from this forum can be integrated into hydropwer options.

The Approach

In Figure 7-1 we present a flow chart which describes the process for selecting one of the six possible preferred hydro system operations in 1999. We begin with a brief description of the paths.

The Paths

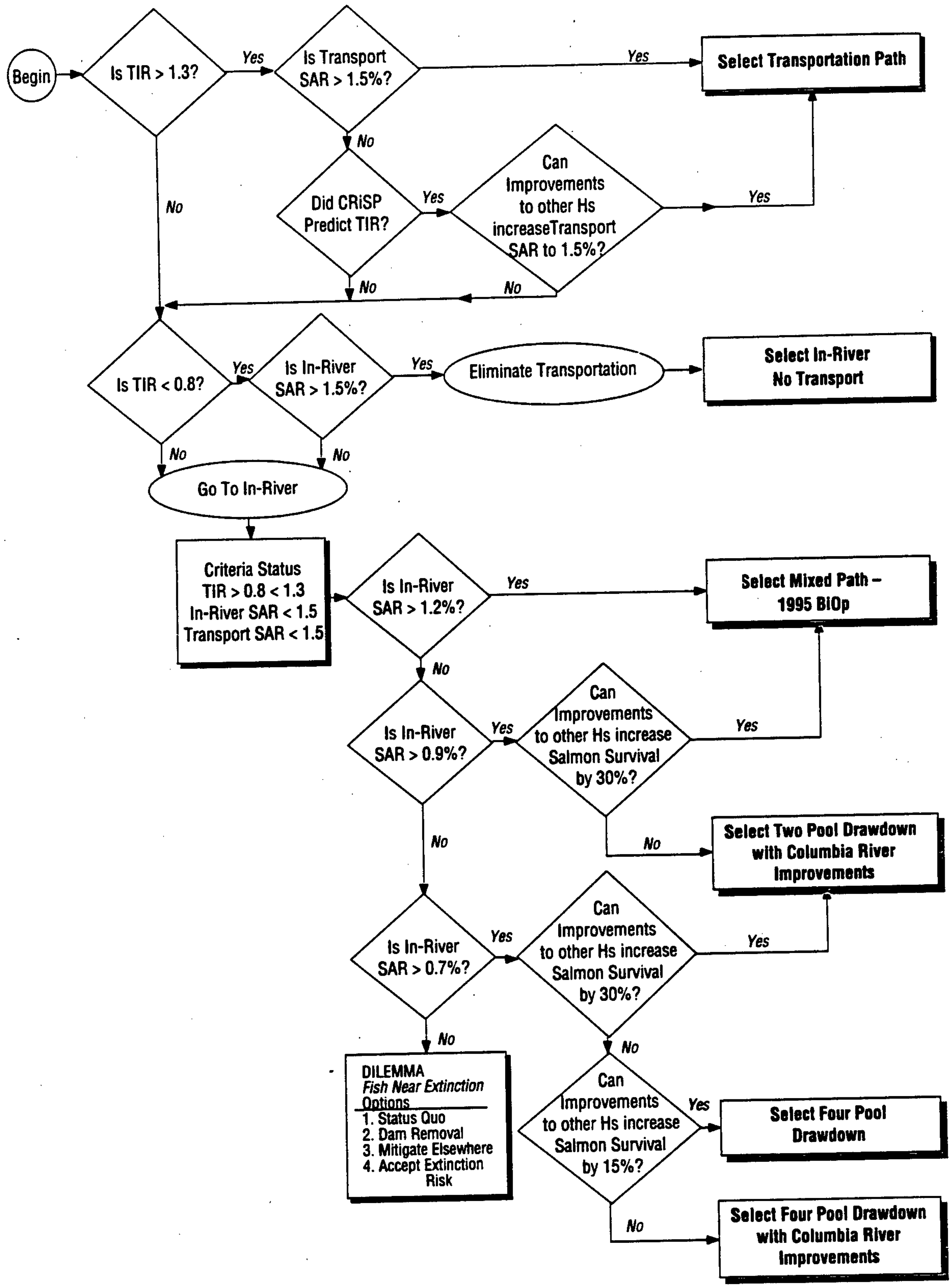
There are six paths/sub-paths that could be implemented in 1999. They are:

1. ***Transportation.*** Under the *Transportation Path*, the collection and transport of juvenile salmonids in the Snake River is maximized.

2. ***Mixed Path — 1995 BiOp.*** This path reflects the current mode of Snake River hydro system operation. Improvements continue to be made at all projects (FISHPASS). The number of juveniles transported is dependent on Snake River flows. More juveniles are transported when river flows are low; less when flows are high.

3. ***In-River — No Transportation.*** Same as for the *Mixed Path* except transportation is eliminated.

Figure 7-1: Path Selection Flow Chart



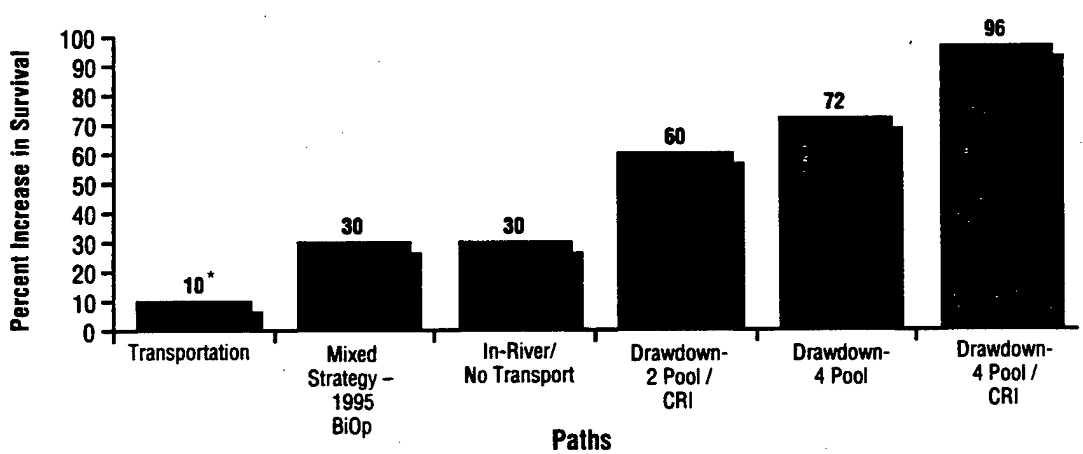
4. ***Drawdown — Two Pool: With Columbia River Improvements***. The embankments at Lower Granite and Little Goose dams are removed. System improvements continue to be made at Lower Monumental, Ice Harbor, and the four Lower Columbia River projects.

5. ***Drawdown — Four Pool***. All four Snake River projects are eliminated by removing embankments. Transportation is eliminated as a recovery tool. No system improvements are made at the four Lower Columbia River projects.

6. ***Drawdown — Four Pool: With Columbia River Improvements***. Same as *Drawdown-Four Pool* except that system improvements continue in lower Columbia.

The overall increase in salmon survival from the implementation of each of the paths is presented in Figure 7-2.

Figure 7-2: Estimated Increase in Salmon Survival for Selected Hydro System Operations (Paths)



* Depending on transport survival (50 percent or 80 percent), overall juvenile survival increases to 55 percent or 88 percent, respectively.

Path Selection Criteria

After identifying the paths to be examined we then establish the biological criteria that will be used to select or eliminate a path from further consideration. The primary selection criteria used in our analysis are the Smolt-To-Adult-Return Rate (SAR) for wild spring/summer chinook observed for each path and the difference between these paths expressed as a ratio called a TIR. A TIR is calculated by dividing the SAR for transported

fish by the SAR for in-river fish. We use the TIR criterion to quantify transport survival. Secondary criteria are also used in path selection and are discussed under each path.

SARs are used as the primary selection criteria because the region's ability to maintain viable populations of Snake River chinook is dependent solely on the number of adults which return to spawn from a given brood year. Regardless of the path selected, the number of adults returning to the spawning grounds from the implementation of the path must be sufficient to maintain these species at genetically viable levels.

However, many factors besides the hydroelectric system (Habitat, Harvest, Hatcheries) affect the number of adults which return from a given brood year. Ideally, because each of the Hs influences the number of wild adults which return to natal streams, the magnitude of each Hs effect would be quantified prior to establishing an adult return rate criteria for path selection. Thus, each path would only be responsible for meeting an adult return rate which mitigated for hydroelectric impacts and not impacts from the other Hs.

Unfortunately, attempting to isolate and quantify the effect each H has on adult return rates is an inherently difficult task and is probably irrelevant for the near term. For example, major improvements in Habitat and Hatcheries will take years to implement and results will not be measurable for decades. Spring chinook harvest has already been reduced to less than 10 percent. Therefore, major increases in survival obtainable from improvements in the other Hs are probably not forthcoming by the 1999 decision point.

If in the near term salmon survival must be increased, this increase will have to be obtained either from the hydro system or from improved ocean conditions. Because we have no control over ocean conditions, our path analysis uses SARs as threshold values to indicate the time frames and level of survival improvement needed from the hydro system to maintain these stocks.

In the 1995 BiOp the NMFS stated that the process for selecting the preferred hydro system operation in 1999 would be one that determines:

> *The adequacy of either in-river migration or transportation to provide sufficient improvements in juvenile survival and a* ***high probability*** (emphasis added) *for stock recovery in the absence of drawdowns.*

Under our approach, if the *Transportation* or *In-river* paths cannot meet specific SAR and TIR criteria we conclude that drawdown is needed. This approach is consistent with, and provides criteria absent from, the 1995 BiOp.

SAR Source/Rationale

We have calculated that the SAR needed to keep these stocks at or above replacement rates is approximately 1.5 percent. This number was calculated based on Idaho Department of Fish and Game (IDFG) estimates of juvenile production to Lower Granite Dam (Keifer, 1996).

The IDFG estimates that for each adult female spring chinook which arrived at Lower Granite Dam in a given brood year, 100 to 200 juvenile migrants are produced to this same point two years later. The actual number of juveniles produced is dependent on migration year, stock, adult pre-spawning mortality, and juvenile survival to Lower Granite Dam, all of which are incorporated into the IDFG estimates. In future years these juveniles must return as adults at a rate of between one percent (2/200) and two percent (2/100) in order to maintain current run size.

Based on the IDFG data we have chosen 1.5 percent (the average of these SAR estimates) as the SAR needed to maintain these stocks. It should be noted that an SAR of 1.5 percent corresponds to a yearly juvenile production estimate to Lower Granite Dam of 130 fish (2/130 = 1.5 percent). Thus, the 1.5 percent SAR is somewhat conservative and if achieved should increase population size over time.

An objection to setting a specific SAR has been that ocean conditions vary annually and can overwhelm either the impacts or the improvements we make in freshwater. Ocean effects on SARs can be accounted for in three different ways: (1) by using TIRs as the primary criterion; (2) developing an index of ocean conditions; and (3) simply assuming that the SAR criteria must be met regardless of ocean conditions. All three approaches have merit and are discussed in different sections of this report.

We have decided to emphasize the last method — SAR criteria must be met regardless of ocean conditions — for our selection process. Our rationale for selecting this approach is simple. It does not seem productive nor honest to place the blame for extinction on the ocean. These stocks have persisted for thousands of years despite ocean conditions which have probably varied substantially from decade-to-decade. Additionally, the focus of this report is to develop a logical plan for selecting a preferred hydro system operation in 1999, not in apportioning blame among the other Hs or the ocean. While in 1999 regional scientists can debate the merits of blaming other factors for the decreased number of adults returning each year, the focus of this report is to identify specific management actions the region can take in regard to hydro system operation to help recover these stocks.

Under our approach, as SARs decrease below threshold values, the region's willingness to consider paths with more risks, uncertainties, costs, and shorter implementation times should increase if saving Snake River salmon is the goal. Each year the SAR criterion is not met decreases the probability that a viable population of Snake River spring/summer chinook can be maintained over time.

The SAR selection criteria used to select between paths are shown in Figure 7-3 and are discussed below.

TIR Source/Rationale

TIR is a path selection criteria for three reasons: (1) to estimate the survival rate of transported juveniles; (2) to allow for comparisons with historical studies; and (3) to maintain a constant comparison value for all possible experimental outcomes.

The survival rate of transported fish is calculated as follows. The survival rate for all in-river treatment groups is calculated based on NMFS reach survival estimates and CRiSP model results. In 1995 this type of analysis was performed on the NMFS in-river control fish and resulted in a survival estimate from Lower Granite Dam to Bonneville Dam of approximately 48 percent (CRiSP model; Anderson, pers. comm., 1996). Assuming a 100 percent survival rate for the NMFS transported juveniles, results in a TIR of 2.1. Upon completion of the experiment in 1998 if the observed TIR falls below this 2.1 value, then the estimate of transport survival decreases. For example, TIRs of 1.5, 1.3 and 1.0 correspond to transport survival rates of 72 percent, 62 percent, and 48 percent, respectively. The specific TIRs used for selecting each path and sub-path are shown in Figure 7-1 and are discussed below by path.

Rationale for Path Selection

Transportation

Under the full *Transportation Path*, the collection and transport of juvenile salmonids in the Snake River is maximized. We use the following criteria in order to select this path.

- **SAR for transported wild juveniles must exceed 1.5 percent.** This meets the principal criterion that the adult return rate for transported fish is high enough for these stocks to persist over time.

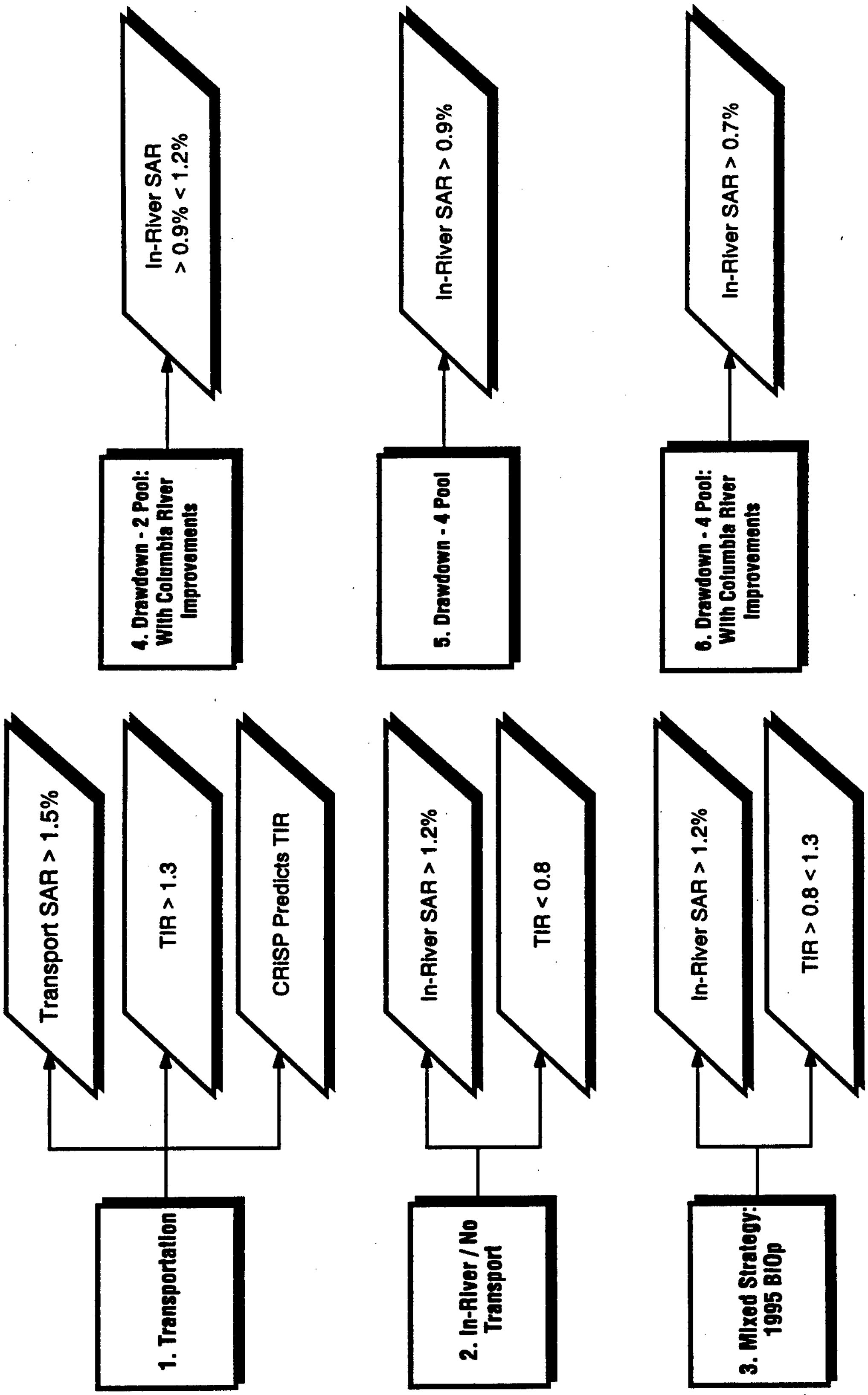
- **The TIR between the *Transportation* and *In-River* paths must be greater than 1.3.** This number represents a 30 percent difference in the SAR between the two groups. The 30 percent value was selected based on the assumption that this is the maximum improvement possible in *In-River* survival with all of the dams in place. If the TIR is greater than 1.3, then only dam removals can increase in-river adult returns to transport levels. If the TIR is less than 1.3, then the *Mixed Path* is selected (see below).

- **CRiSP modeling results of mainstem juvenile passage survival must be able to predict the resulting TIR obtained from the NMFS Transportation Study.** The CRiSP prediction is used to confirm the juvenile survival estimate from the tailrace of Lower Granite Dam to Bonneville Dam for Snake River spring/summer chinook (48 percent). For the 1995 NMFS in-river control group CRiSP predicts that the resulting TIR will be about 1.8. If the CRiSP prediction is accurate, juvenile transport survival is assumed to be within CRiSP estimates (80-100 percent). A *Transportation* survival level of 80 percent exceeds the juvenile survival level of all other paths including a four pool drawdown, therefore eliminating the drawdown paths from further consideration. The 1995 and 1996 transportation evaluations being conducted by the NMFS are critical to verifying this assumption (Section 11).

- **There must be no evidence of adult homing impairment on transported fish.** This criterion is basically a comparison of the TIR and adult losses at various locations in the Columbia and Snake rivers. The TIR between transported and in-river adults is compared at four locations: Bonneville, McNary, Lower Granite, and the spawning grounds. A decreasing TIR from downstream to upstream adult PIT-tag detection sites indicates homing impairment. Additionally, because adults from transport or in-river groups may not be detected equally at projects with more than one fish ladder, survival rates are compared between detection sites as a second method for determining homing impairment. *This criterion does not have to be met in order to select the path. The purpose of this criterion is to determine if the transportation program can be improved, thereby increasing overall salmon survival.*

If the *Transportation Path* can satisfy these criteria it should be sufficient evidence to convince NMFS staff that the selection of this path has a "high probability" of maintaining these stocks over time. However, if only two or three of the criteria are met, then it will be up to NMFS to decide which criteria are more important for meeting recovery objectives. For example, the NMFS may be willing to lower the SAR criteria for the *Transportation Path* if survival improvements can be gained from improvements in the other Hs within a reasonable period of time. Or the NMFS may decide to emphasize the TIR criterion over the SAR as TIRs are a measure of overall juvenile survival through the system for the two

Figure 7-3: Path Selection Criteria for Six Major Options



major paths: *In-River* and *Transportation*. The lower the SAR however, the greater the risk of extinction, no matter what the TIR value.

Eliminate Transportation

The criteria for eliminating transportation as a recovery tool in any of the paths is a TIR of less than 0.8 (Figure 7-1). Essentially, this is the inverse of a 1.3 TIR where 30 percent more in-river wild adults return compared to transport. Why would we transport if more fish return by natural migration?

Mixed Path — 1995 BiOp

This path reflects the current mode of Snake River hydro system operation. Improvements continue to be made at all projects (FISHPASS). The number of juveniles transported is dependent on Snake River flows. More juveniles are transported when river flows are low; less when flows are high.

- **An In-river SAR of 1.2 percent or greater and a TIR ranging from 0.8 to less than 1.3 are needed to select this path.**

  And/Or

  TIR estimates vary above and below 1.3 by year.

  These results indicate that the existing system (dams in place) is within hailing distance of achieving the needed SAR of 1.5 percent. Additionally, transport survival may be about equal to in-river survival in some years and greater than in-river in others. We have calculated that a 30 percent gain in in-river juvenile survival can be achieved through various means (surface collectors, baffles, extended screens, etc.). This assumes that current juvenile survival from Lower Granite Dam to below Bonneville dam is approximately 43 percent (90 percent survival per project). We estimate that new technology can increase per project survival from 90 to 93 percent by meeting the 80 percent FPE and flow target goals established in the NMFS BiOp. This should result in a system survival rate of 56 percent.[2]

The selection of the *Mixed Path* as the preferred hydro system operation may also occur if study results vary significantly by year. The most likely scenario will be where in low flow

[2] Assumes project survival is increased at the four Snake River and four Columbia River projects (0.93^8)

years TIRs exceed the 1.3 criteria and in high flow years they do not. The primary goal of the *Mixed Path* is to maximize juvenile survival under each path. This will be achieved by meeting FPE and survival targets and emphasizing the path that best mitigates hydro system impacts dependent on river condition.

In-River Path

This path is the same as the *Mixed Path* with the exception that juvenile transportation in the Snake River is eliminated. System improvements continue to be made at the four Lower Snake and Columbia River projects. The overall improvement in salmon survival from this path is the same as for the *Mixed Path*, i.e., 30 percent.

Drawdown — Two Pool: With Columbia River Improvements

Under this path, the embankments at Lower Granite and Little Goose dams are removed. System improvements continue to be made at Lower Monumental, Ice Harbor, and the four Lower Columbia River projects.

- **An In-River SAR of between 0.9 percent to less than 1.2 percent, and a TIR ranging from 0.8 to less than 1.3 are needed to select this Sub-Path.** These numbers reveal that both the *Transport* and *In-River* SARs are below the 1.5 SAR criterion. The improvement in juvenile or adult survival needed to reach the 1.5 percent SAR criterion ranges from 30 percent to 60 percent. We have suggested that the maximum improvement obtainable from the existing system is 30 percent, therefore the only hydro system option remaining is project removal. The number of projects to be removed (two) is based on the assumption that for each project removed provides a 10 percent increase in juvenile survival and a three percent increase in adult survival. The two-pool drawdown in combination with system improvements at the other two Snake River and four Lower Columbia River projects could increase overall salmon survival by as much as 60 percent.

A point that needs to be emphasized under all *Drawdown* paths is that improvements to the other Hs are taken into consideration but not quantified. Prior to the 1999 decision point it is expected that the PATH process will have quantified the level of survival improvement possible from outside the hydropower system and time frames for expected improvements. These data can then be factored into the path selection process and changes made accordingly. If analysis from the PATH process indicates that SAR criteria for the drawdown scenarios is too high (or too low) criteria can be changed.

The SAR criteria presented for the *Two-Pool Drawdown Path* may present NMFS with a dilemma. If we obtain 1996 to 1999 SAR data in the 0.9 to 1.2 range, such results are close enough to 1.5 to suggest that the existing system (*Mixed Path - BiOp*) is working. NMFS may conclude it would be prudent and biologically justified to continue with BiOp actions, i.e., spill and transportation. The dilemma occurs only if data fall close to the line. To remain objective, criteria and decision paths should be set before 1999.

Drawdown — Four Pool

All four Snake River projects are eliminated by removing embankments. Transportation is eliminated as a recovery tool. No system improvements are made at the four Lower Columbia River projects.

- **This path is selected if the SAR for the In-River groups are less than 0.9 percent.** A 70 percent or greater improvement is needed in juvenile or adult survival. The only hydro system solution available to obtain a 70 percent or greater increase in survival is to remove the four lower Snake River projects. The overall increase in juvenile/adult survival possible with the removal of the four Snake River projects is about 72 percent which increases the SAR to the 1.5 percent level.

Drawdown — Four Pool: With Columbia River Improvements

As SARs reach the 0.7 percent level, survival improvements will be needed from the Lower Columbia River and other Hs to meet the 1.5 percent SAR criterion. Although no estimates were made of the survival improvements possible from the other Hs, we have calculated that an additional 14 percent increase in survival could be obtained from the Lower Columbia River if per project survival could be improved from an estimated 90 percent to 93 percent. This would increase overall salmon survival under this path to approximately 96 percent. Thus, an SAR of about 0.7 percent could be increased to meet the 1.5 percent SAR criterion.

A Possible Dilemma

If SARs continue to return below some minimum threshold value, say 0.7 percent, then it may be that no combination of improvements at the dams (without help from the other Hs) will be sufficient to achieve the 1.5 percent SAR criterion. Under this scenario the stocks will be on the actual brink of extinction and a decision needs to be made regarding

whether or not there is enough time and enough fish remaining to justify the risks, uncertainties, and costs associated with major hydro system alterations such as project removals. At this point the region has three options:

1. Maintain the status quo and hope ocean conditions improve.
2. Implement the *Four Pool Drawdown Path* immediately with the risk that these stocks may go extinct before or during path implementation.
3. Accept the high risk of extinction without project removals and use federal hydropower dollars to improve fish runs in the Columbia River or other basins.

In other words, these are the same exact choices the region is faced with today. The differences being that the decision point was moved back three years, the stocks may be closer to extinction, less time is available for path implementation, and path costs have increased.

Meeting Criteria Assumptions

A major assumption of this path selection process is that the TIR measures the amount of delayed mortality occurring to transported juveniles. This also assumes that reach survival estimates accurately reflect juvenile survival through the system and that in-river migrants experience little delayed mortality after passing Bonneville dam.

An exceptionally high TIR, say 3.0 or greater, would indicate that in-river migrants are experiencing some level of delayed mortality. Such a study result would mean that transported fish produced three times as many adults as in-river fish. If transport juvenile survival ranges from 80 to 100 percent, then in-river survival is only 26 to 33 percent. A 26 to 33 percent in-river survival rate is significantly less than the 40 to 50 percent survival estimate used for the in-river migrants in our analysis.

We would interpret a high TIR (>3.0) as meaning that some other factor besides direct hydro system induced mortality are affecting the survival rate of in-river migrants. Possible causes for delayed mortality include: (1) multiple exposure to juvenile bypass systems, (2) high river TDG levels, and (3) increased juvenile travel-time.

The effect a high TIR would have on path selection is not clear. Some would argue to stick with the transportation program while others would claim that this result supports the *Drawdown Paths*. We would review the SAR values of each path and weigh risks of extinction. Anticipating more equivocal data in 1999 is why there is some rationale for a Decision 1996 (Section 6).

Path Goals

For each path, there are specific goals. For example, under the *Transportation Path* (Figure 7-4), 90 percent fish collection at Lower Granite is the goal. For the *In-River* and *Mixed Paths*, 80 percent fish passage efficiency (FPE) and BiOp flow targets are the goals. For *Drawdowns*, the goals are a 30 to 96 percent increase in salmon survival.

In the following section, we describe the goals for each path as well as the rationale for their selection.

Transportation

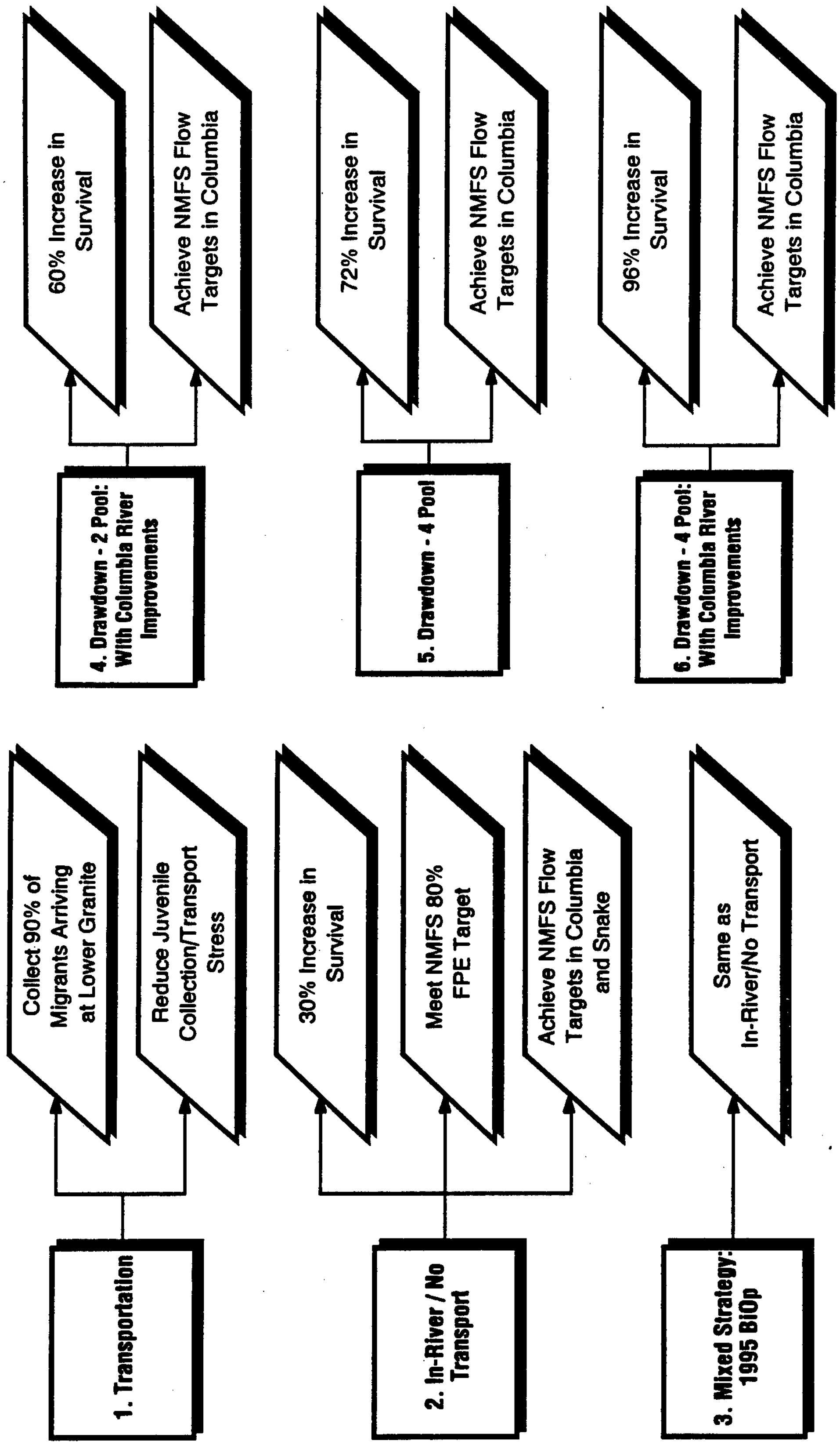
The goals for the *Transportation Path* are as follows:

1. **Collect 90 percent of all juvenile migrants arriving at Lower Granite Dam.** The 1.5 percent SAR is based on an assumption of wild juvenile production to Lower Granite Dam. Thus, to meet the SAR as many juveniles as possible must be collected and transported from this facility. Because high river flows and resulting spill will occur from time-to-time, it is doubtful that 100 percent collection efficiency could ever be achieved. We have therefore established a 90 percent collection level at Lower Granite dam as our target goal. Collection facilities at Little Goose and Lower Monumental dams will still be used to collect those migrants which were not collected at upstream projects. Tools to increase FGE are discussed in Section 4.

2. **Reduce juvenile collection and transport stress.** The collection and transport of juveniles from collector facilities is not a benign process. Handling juveniles increases stress, the chance for physical injury, and increased disease transmission. These handling impacts can be reduced by improving collection facilities, loading all juveniles directly into barges, decreasing loading rates, sorting by size, and improving barge release mechanisms. The Corps has proposed these changes in the SOR and will be implementing most in the near future (Section 3, Changes Affecting Salmon).

   An increase in collection efficiency and a reduction in handling stress will help to maximize the SAR for this path. Another improvement that may increase SAR is the changing of the downstream release point for barged fish. However, we consider this a long-term, highly experimental program that will take years to adjudge. It was, therefore, not included as a specific goal in the *Transportation Path*. This action is however recommended for further study.

Figure 7-4: Path Goals for Six Major Options



Mixed Path — 1995 BiOp and In-River — No Transportation

There are three goals for these paths. These are:

1) Increase in-river juvenile survival by 30 percent.
2) Meet 80 percent FPE target for all eight mainstem dams.
3) Achieve NMFS flow targets for the Snake and Columbia rivers.

The primary goal for these paths is to increase juvenile survival by 30 percent, the improvement needed to meet the 1.5 percent SAR previously described. This increase can be achieved by increasing project FPE and reducing juvenile travel time through the system. Because turbine mortality is about 10 percent or less, each 10 percent incremental improvement in FPE only yields a one percent or less survival benefit (Table 7-1).

Given that current FPE at most Snake River projects is around 50 to 70 percent, an increase in FPE to 80 percent results in a one to three percent increase in juvenile survival per project.

Table 7-1: Effect of FPE on Project Survival

FPE	Fish Entering Turbine	Turbine Mortality[1]	Turbine Passage Survival
90%	10%	1%	99%
80%	20%	2%	98%
70%	30%	3%	97%
60%	40%	4%	96%
50%	50%	5%	95%

1 Assumes 10 percent turbine mortality

Increases in juvenile survival from a reduction in juvenile travel time through the system are uncertain, but according to CRiSP Modeling results are probably in the one to two percent range depending on various biologic (stocks) and physical (water temperature) parameters.

Thus, overall project survival (currently 90 percent) can probably be increased by about three percent to 93 percent. A 93 percent project survival equates to a 56 percent system survival ($.93^8$) or a 30 percent increase in the current system survival estimate of 43 percent.

Drawdown — Two and Four Pool

The goals for either the *Two Pool* or *Four Pool* paths are similar. The goals are to increase juvenile/adult survival rates and to meet the NMFS flow targets for the Columbia River. The only major difference between the paths is the total benefit in survival needed to meet the 1.5 percent SAR criterion: 30 to 60 percent for the two pool versus 72 percent to 96 percent for the four pool option.

The increase in juvenile and adult survival possible per project removed was calculated on the assumption that all project-related mortality is eliminated upon dam removal. The maximum increase in juvenile and adult survival obtainable by removing a single Snake River dam is estimated at 10 percent and three percent, respectively. These numbers are based on juvenile reach survival estimates collected recently by the NMFS and adult survival estimates developed by Bjorn et al., (1992). Juvenile survival increases for the remaining projects are based on the same assumptions as for the *Mixed Path*.

Tools

Tools which can be used to achieve path goals are described in Section 4.

Future tool selection will be based on the path selected (*In-River*, *Transportation*, *Mixed*), the specific biological objectives for that path, cost, and biological risks associated with tool usage.

The equivalent annual costs for each of the major tools are presented in Figure 7-5. The costs range from a high of $153 million for a four pool removal (Permanent Natural River) to a low of $0.5 million for a sound diversion system.

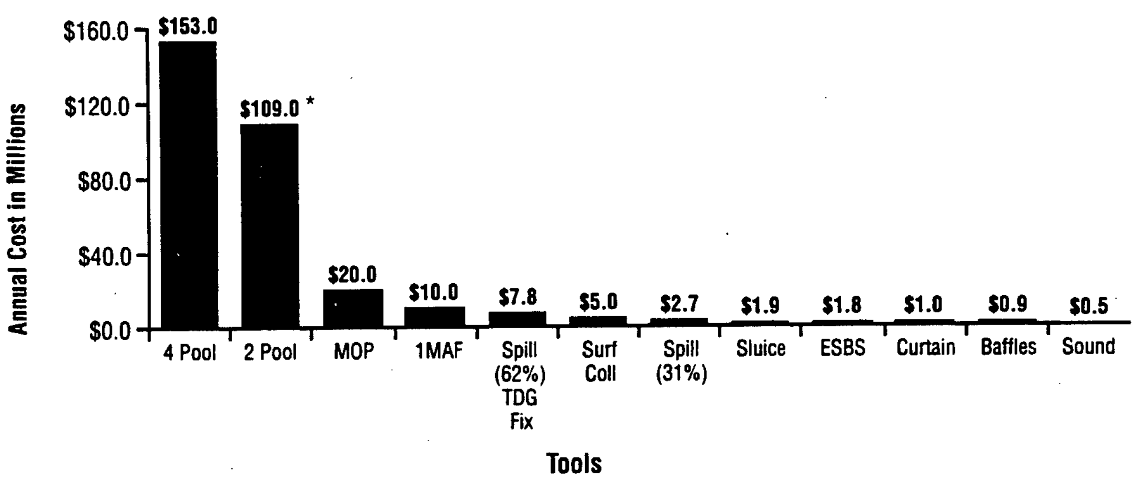
A comparison of the annual costs versus percent gain in salmon survival for each of the major tools is presented in Figure 7-6. Cost per one percent gain in salmon survival range from a high of $5 million for flow augmentation (1 MAF) to a low of $0.1 million for a sound repulsion system.

The costs used in developing Figure 7-5 are from Section 8, Costs. The survival numbers used in Figure 7-6 are more complex and are explained for each tool or group of tools below.

Two or Four Pool Drawdown. For each Snake River dam removed, juvenile and adult

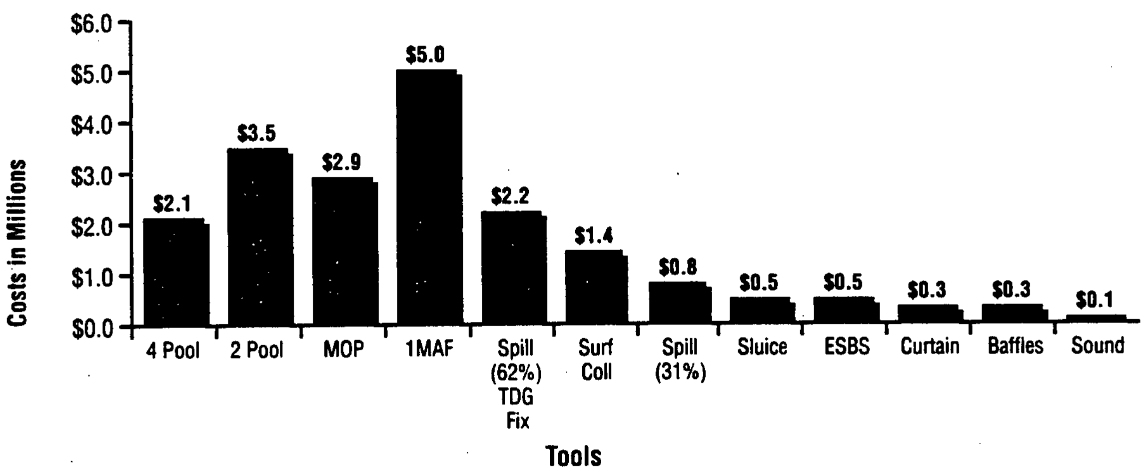
survival is increased by 10 percent and three percent, respectively. Thus, a two pool drawdown increases salmon survival by about 30 percent while a four pool drawdown increases survival by 72 percent.

Figure 7-5: Average Annual Equivalent Cost of Hydro System Improvement Tools



* Power losses from two pool were estimated the same as four pool because no model data are available for two pool; actual total cost is lower.

Figure 7-6: Average Annual Equivalent Cost for Each One Percent Gain in Salmon Survival for Hydro System Improvement Tools



MOP. All four Snake River projects are operated at minimum operating pool (MOP). Olsen (1992) estimated that MOP provided a five percent increase in overall reservoir survival (four projects).

Flow Augmentation (1 MAF). CRiSP modeling of flow augmentation through the system indicate that the first 1 MAF increases juvenile survival through the system about 2.5 percent under low flow and less than one percent under high flow river conditions (Appendix B). We use two percent for display purposes.

Spill, Surface Collector, ESBS, Sluiceway, Curtain, Baffles, Sound. It is assumed that each tool is capable of increasing current project FPEs to the NMFS mandated 80 percent FPE goal. Thus, project (reservoir/dam) survival increases from 90 percent to 93 percent.

Tool Costs — Trade-Off Analysis

A review of the data presented in Table 7-2 allows for a quick comparison of tool cost and relative value in comparison to other tools. For example, the cost of MOP is estimated at $20 million or the same as the costs of two MAF of storage or spilling nearly two-thirds of the river at three projects including stilling basin reconstruction. For the same cost, you could construct and operate new surface collectors at virtually all eight mainstem dams.

Using the same data, costs can be developed for a preferred hydro system mitigation package. For example, a system for the four Snake River projects which used a combination of ESBSs ($1.8*4), 31 percent spill ($2.7*4), and 4 MAF of flow augmentation ($10*4) to protect salmon would cost $58 million annually.

The data displayed in Figure 7-5 are also useful for establishing both tool performance and setting research priorities. From these data it is apparent that a surface collector costs twice as much as spill. Therefore, it must be able to pass approximately twice the number of fish with a similar survival rate as a 31% spill program in order to be effective from both a biologic and cost perspective. Monitoring and evaluation dollars would be best spent examining whether or not relatively low cost tools such as, sluiceways, baffles, curtains or sound systems can achieve NMFS biological objectives for the hydro system.

Table 7-2: Cost Equivalent for Selected Hydro System Improvement Tools

	MOP	1 MAF	Spill (62%)	Surface Collector	Spill (31%)	Sluice	ESBS	Curtain	Baffles	Sound
MOP (4 dams)		2.0	2.6	4.0	7.4	10.5	11.1	20.0	22.0	40.0
1 MAF	0.50		1.3	2.0	3.7	5.3	5.6	10.0	11.0	20.0
Spill (62%)	0.39	0.78		1.6	2.9	4.1	4.3	7.8	8.6	15.6
Surface Collector	0.25	0.50	0.64		1.9	2.6	2.8	5.0	5.5	10.0
Spill (31%)	0.14	0.27	0.35	0.54		1.4	1.5	2.7	3.0	5.4
Sluice	0.10	0.19	0.24	0.38	0.70		1.1	1.9	2.1	3.8
ESBS	0.09	0.18	0.23	0.36	0.67	0.95		1.8	2.0	3.6
Curtain	0.05	0.10	0.13	0.20	0.37	0.53	0.56		1.1	2.0
Baffles	0.05	0.09	0.12	0.18	0.34	0.48	0.51	0.91		1.8
Sound	0.03	0.05	0.06	0.10	0.19	0.26	0.28	0.50	0.55	

Information as to the biological effectiveness of each tool in comparison to dollars spent are shown graphically in Figure 7-6. This information is useful for eliminating tools that provide limited or reduced survival benefits. For example, it appears that the tools of MOP and flow augmentation (1 MAF) are providing limited benefits at high costs while spill (31 percent) is providing high benefits at a relatively low cost.

Tool Performance Criteria

The last step in the path analysis involves the establishment of performance criteria for selected tools. The primary performance criterion for most *In-River* paths and tools is to achieve the NMFS mandated 80 percent FPE and 95 percent project survival at all four Snake River Projects. The major exception to this rule is for the project removal options which will increase salmon survival rates above NMFS standards. Secondary performance criteria include increased FGE, a reduction in juvenile travel time through the hydroelectric system, and cost-effectiveness.

Spill is the baseline upon which all *In-River* tools are adjudged. For comparisons, one percent spill equates to an increase in FPE of one percent at an annual cost of $87,000 per 1,000 cfs. Juvenile mortality through a spillway was also assumed to be two percent. The resulting tool performance criteria, expressed as spill equivalents, are presented in Table 7-3.

Table 7-3: Performance Criteria Expressed as Spill Equivalents for Selected Hydro System Improvement Tools

Tool	Cost (Millions)	Spill Equivalents (cfs)*
Surface Collector	5.0	57,400
Sluiceway	1.9	21,800
ESBS	1.8	20,600
Curtain	1.0	11,500
Baffles	0.9	10,300

* Spill equivalents assume that one percent spill passes one percent of the juvenile migrants. arriving at a project. Hydroacoustic monitoring needs to verify this assumption at each project.

The data in Table 7-3 establish the performance criteria for each tool. For example, a surface collector must provide similar biological benefits as 57,400 cfs of spill, a sluiceway 21,800 cfs, and a baffle 10,300 cfs in order to be cost effective. Otherwise it is less expensive to use spill to meet project FPE and survival targets until TDG standards are exceeded. At this point, tools which also reduce TDG levels are preferred. A tool can be selected regardless of cost effectiveness if: 1) it is the only tool available that will achieve path goals, or 2) provide additional biologic benefits beyond those achieved with spill.

Spill discharge and their resulting TDG levels vary by project and release time (Table 7-4). Therefore, if spill equivalents are to be used as performance criteria they must be developed at each project.

Table 7-4: Estimated Spillway Discharge and Associated Tailwater TDG Levels

Project	Spillway Flow @ TDG 110% (kcfs)	Spillway Flow @ TDG 115% (kcfs)	Spillway Flow @ TDG 120% (kcfs)
Lower Granite	21.1	41.1	61.1
Little Goose (nighttime)	20.8	36.0	51.2
Little Goose (daytime)	17.9	27.4	36.8
Lower Monumental (nighttime)	3.0	20.8	38.7
Lower Monumental (daytime)	6.5	14.0	21.5
Ice Harbor	12.6	15.6	27.0
McNary	0.0	60.3	130.7

Section 8

COSTS AND ECONOMIC TRADE-OFFS

Section 8 COSTS AND ECONOMIC TRADE-OFFS

General Framework for Economic Evaluation

The *In-River* and *Transportation* strategies examined in this report include four general categories of juvenile passage activities: 1) reservoir drawdowns at one or more of the four Lower Snake projects; 2) barge transportation of juvenile fish to release points below Bonneville Dam; 3) structural modifications to existing projects to improve juvenile passage past the dams; and 4) diversion of river flows to project spillways during spring and summer migration to improve juvenile passage survival. Implementation of any of these actions would be associated with a set of economic costs that reflect the costs for project construction and facility modifications and the opportunity costs for economic activities that are affected by changes in hydro system operations.

Measures of Economic Costs

The direct economic effects of the alternative juvenile migration strategies are measured by changes in the value of the commodities and activities directly affected by modifications to river system operations or project configurations and by the costs to implement the Path strategy. The first set of costs are generally referred to as economic opportunity costs while the latter are described as project implementation costs. The basis for the cost estimates developed for this report are the detailed studies prepared for the System Operation Review and the Phase I System Configuration Studies.[1]

National Economic Development (NED) guidelines and principles for the evaluation of water resource-based projects are used to measure the economic opportunity costs for the

[1] A more detailed discussion of the economic analysis developed for the SOR and SCS studies is presented in Appendix C, Economic Costs.

path alternatives.[2] Opportunity costs reflect the economic value of changes in the production of goods and services that would occur with implementation of alternative strategies. The primary economic activities that would be affected by the structural and operational changes required under the Lower Snake path alternatives include hydropower generation, reservoir recreation, commercial barge navigation, and irrigation and municipal water supply. A brief description of the direct measures of economic change for the opportunity costs and project implementation costs are presented below.[3]

Table 8-1: Economic Measures Used to Value Expected Changes in River Uses

Resource Activity	*Measure of Direct Economic Impact*
Project Implementation	Construction costs associated with project implementation requirements, including investment costs, interest during construction and annual operations and maintenance.
Hydropower	Changes in regional power costs, including system operations costs and new resource costs.
Reservoir Recreation	Changes in recreation visits and the associated willingness-to-pay values for reservoir recreation activities under alternative reservoir operations.
Navigation	Changes in commodity shipping costs related to changes in shipping routes and shipping modes under alternative reservoir operations.
Irrigation and Municipal Water Supply	Changes in pumping costs related to necessary pump modifications, increased operation and maintenance costs, and increased energy costs.

2 US Water Resources Council, Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies, March 10, 1983.

3 Analysis developed for the SOR and the SCS studies indicated that the recovery options being examined in the *Salmon Decision Analysis* are not likely to result in significant changes in the economic costs related to flood control. Therefore, these costs were not considered in this analysis.

Time Frame for Evaluation

Modifying the operations strategy for the Columbia-Snake River system will necessarily result in long-term changes to the activities and environments of the region's river-based resources. The magnitude of the economic impacts associated with the modified operations depend, in part, on the length of time required to fully implement the revised plan. Strategies which require longer time periods to carry out (e.g., extensive dam modifications) will not result in economic changes for many years after a strategy that can be implemented without delay. In order to compare the economic trade-offs for operating strategies with different implementation dates, the values must first be expressed for comparable points in time. To accomplish this, the economic costs associated with an operations strategy are discounted from the implementation year to the current year, 1996. These current cost estimates are referred to as annual equivalent values since costs expected to occur at different points in time have been converted to a common time frame. These equivalent costs can be included with other factors describing the environmental outcomes of both strategies to assist decision-makers in the selection of one plan over the other.

The economic costs of the path options are compared over a 100-year time frame. Differences in implementation dates are accounted for using a discount rate of 7.75 percent. Constant prices are assumed throughout the evaluation period, using a 1996 base year. This is consistent with the planning framework developed for the SOR and SCS Phase I studies. All costs have been adjusted to 1996 dollars.

Expected Economic Benefits

Recovery of the Snake River salmon and protection of their natural environment will yield significant environmental, cultural, and economic benefits to the region. In some cases, recovery efforts will yield tangible benefits: increased survival will lead to larger numbers of fish which in turn will support higher levels of sustained harvest opportunities for commercial, recreational, and cultural uses. Intangible benefits include the preservation of biological diversity, the protection of river habitat, and the protection of Native American cultural values. This report considers only the biological benefits associated with alternative path options. No attempt is made to measure the associated economic benefits, since recovery objectives do not require an analysis of these effects. Economic trade-offs are presented in terms of the economic costs required to achieve alternative levels of biological benefits.

Economic Costs for the Existing Operation

The present operations of the Lower Snake portion of the Columbia-Snake river system reflect the operational requirements laid out in the 1995 NMFS Biological Opinion. Current actions reflect a mixed operations strategy, combining juvenile transport with project spill to achieve the stated goal of 80 percent fish passage efficiencies at the Lower Snake projects. The current NMFS recovery plan is the basis from which future decisions regarding alternative regional recovery strategies will be evaluated. Therefore, current system operations is considered to be the appropriate basis from which to measure the incremental fish benefits and economic costs associated with alternative recovery options evaluated in this report.

A comparative analysis of the economic costs associated with the system operations outlined in the recovery plan were prepared as part of the System Operation Review. The Preferred Alternative from the SOR represented the operational requirements of the recovery plan; costs of the alternative were measured relative to 1992-93 hydro system operations. The current system operation defined for this report includes a significant modification to the operations specified in the SOR. The year-round drawdown of the John Day reservoir to minimum operating pool (MOP) in the SOR preferred alternative is excluded from the current analysis. The operation has been omitted because of the limited biological benefits associated with the drawdown. Consequently, all economic costs associated with the operation of John Day at MOP have been excluded from the decision analysis, including costs related to project implementation, hydropower generation, recreation, and water supply. All cost figures presented for current operations have been adjusted accordingly. The economic costs of the SOR preferred alternative were estimated to be $152 million relative to 1992-93 hydro system operations. Removing the John Day MOP adjusts the estimated annual economic costs downward to $125 million.

Table 8-2: Economic Costs of Current System Operations, $1,000,000

$1996 average annual equivalents, measured as changes from 1992-93 System operations

Economic Cost	SOR Preferred Alternative	Current Operations for Path Analysis [1]
Project Implementation	$10.3	$0
Power	$116	$116[2]
Reservoir Recreation	$25.9	$9.5
Navigation	$0	$0
Water Supply	3/	3/
Total Economic Costs	$152.2	$125.5

[1] Current operations exclude year-round operation of the John Day pool at MOP.

[2] The hydropower costs associated with the John Day MOP operation are currently being estimated by the Corps and should be available during August 1996. Removing the effects of the John Day drawdown will lessen the power costs for current operations.

[3] Economic costs for water supply are related to pump modifications required under drawdown of the John Day pool to MOP. These impacts are included in the cost estimates for project implementation.

Transportation Path

Objective for Juvenile Passage

The full *Transportation Path* focuses on exclusive use of the Corps' Juvenile Fish Transportation Program as the means to aid juvenile salmon past the Columbia river dams. The path seeks to maximize collection efficiency at each of the Lower Snake collector projects (Lower Granite, Little Goose, and Lower Monumental). Juvenile fish would be collected and transported around the dams and reservoirs to avoid the cumulative mortality associated with passage through the hydro system.

Possible Sub-Paths[4]

1. Existing transportation collection systems.
2. Improved transportation collection and bypass systems.

[4] Improvements to the juvenile transportation program identified in the NMFS Biological Opinion would be incorporated into all of the full *Transportation* sub-paths.

a. Screened surface collectors (SC) at one, two, or three of the Lower Snake projects (LGR, LGO, LM).

b. Extended-length screens (ELS) at one or two Lower Snake projects (LM, IH).

c. Combinations of surface collectors and extended-length screens at one or more Lower Snake projects.

General Description of Hydro System Operation

The *Transportation Sub-Paths* incorporate improvements to juvenile collections systems in order to meet or exceed the goal of collecting 90 percent of the juvenile fish arriving at the Lower Snake projects. For purposes of illustrating the potential economic costs related to the full transportation strategy, it is assumed that the hydro system would be returned to system operations prior to implementation of the 1980 Northwest Power Act, without fish flow or fish spill requirements. The optimum load following alternative defined for the System Operation Review (SOS 1b) represented hydro system operations as they existed prior to 1980. Hydro system benefits related to power were maximized under the optimum load following alternative. This scenario is used as the operations backdrop for the full *Transportation Path.* Economic costs are measured as differences from the current system operations defined for this report.

Consideration of Economic Trade-Offs

The expected economic costs associated with the implementation of a full transportation program include both project implementation costs and economic opportunity costs. Economic values are presented in terms of average annual equivalent costs, which take into account the differences in the time period required for implementing the various structural modifications designed to increase collection efficiencies.

The economic opportunity costs related to a full transportation strategy depend almost exclusively on the hydro system operations used in conjunction with the program. Shifting the hydro system to a strategy which focuses on maximizing power production under pre-fish flow operations would likely reflect the upper bound on the economic cost-savings associated with the *Transportation Path.*

Construction Costs

Construction costs for a full-scale screened surface collector suitable for transportation

collection are estimated to be $25 million, translating to an annualized cost of $2.3 million. Surface collectors are expected to require three years for project design and construction, resulting in an annual equivalent cost of $1.9 million.[5]

As an alternative to surface collectors, sluices could be utilized to improve juvenile collection rates. Sluices provide a lower cost alternative to surface collectors although with lower associated FPEs. Construction costs for a sluice are estimated at $10 million,[5] resulting in annual costs of $1.0 million.[6] Sluices would also require three years for design and construction for associated annual equivalent cost of $0.8 million.[6]

Extended-length screens are currently in place at Lower Granite and will be installed at Little Goose in 1997. The screens could be added at Lower Monumental, improving collection rates at the existing bypass facility. Adding screens at Ice Harbor, a non-collection facility, would provide some improvement to survival rates for the juveniles that remain in-river. Extended-length screens have estimated construction costs of $26 million.[6] Three and one-half years would be required for design and implementation, resulting in an annual equivalent value of $1.8 million.

Power Costs

Power system impacts under the current system operations reflect the significant amounts of water that must be stored in fall and winter to meet spring and summer flow targets and spill requirements. As a result, replacement energy must be purchased during the fall and winter period when West Coast energy and capacity market prices are at their highest. Shifting hydro system operations to a strategy more favorable to power production results in a significant decline in the power costs associated with the *Transportation Path*. Using figures developed for the SOR, it is estimated that power cost savings would average $186 million annually.[7]

Surface collectors at one or more of the projects to increase collection efficiencies will necessarily require flows of approximately 10,000 cfs to be diverted from the turbines to the collector. This is a hydraulic requirement of about 10 percent of springtime flows.

5 Personal communication, US Army Corps of Engineers, Walla Walla District, June 1996.

6 System Configuration Study, Phase I, Appendix E, Improvements to the Existing System Technical Report.

7 Current West Coast energy market prices are somewhat lower than those used in the SOR analysis; these trends are forecasted to continue for several years. Therefore, the power cost savings associated with this alternative are likely to be lower than the estimated $186 million. Revised estimates based on updated market prices are likely to be available from BPA during Fall 1996.

Estimated hydropower losses associated with surface collector operations is approximately \$3.6 million annually.[8] Sluice operations also require a small portion of project flows (approximately 3,000 cfs) to be diverted away from the turbines, resulting in estimated annual losses of \$0.5 million.

Recreation Costs

Shifting hydro system operations to a regime more focused on power production has only limited effects on reservoir recreation. Negligible changes in recreation activity occur in the Upper Columbia and Lower Snake subbasins; the primary effect is to increase recreation at John Day reservoir by about ten percent. Under the SOR optimum load following alternative John Day would be operated to maximize power production; the reservoir would be held within three feet of maximum pool year-round. Higher average pool levels would be expected to result in an increase in recreation benefits of \$18.3 million annually.

Other Issues

Navigation would be unaffected by the shift in hydro system operations under the *Transportation Path*. Irrigation and M&I water supply would also be unaffected.

Summary of Economic Trade-Offs

The economic costs associated with various options for the full *Transportation Path* are summarized below. These figures can be reviewed in conjunction with the biological and engineering information to determine a preferred transportation strategy.

[8] Estimated hydropower losses related to surface collectors and sluices are presented in Appendix C, Economic Costs.

Table 8-3: Economic Costs Under Full Transportation, $1,000,000

Average annual equivalents in 1996 dollars, measured as changes from current operations

Transportation Alternative	Total Costs	Construction Costs	Power Costs[1]	Recreation Costs
Existing Transportation	($204.3)	$0	($186)	($18.3)
System Improvements[2]				
Surface Collector (*1 project*)	($201.5)	$1.9	($185.1)	($18.3)
Surface Collector (*3 projects*)	($195.9)	$5.7	($183.3)	($18.3)
Sluice (*1 project*)	($203.0)	$0.8	($185.5)	($18.3)
Extended Screens (*2 projects*)	($200.7)	$3.6	($186)	($18.3)
S.C. & Screens (*1 project/2 projects*)	($197.9)	$5.5	($185.1)	($18.3)
S.C. & Screens (*3 projects/1 project*)	($194.1)	$7.5	($183.3)	($18.3)

[1] Power costs still include the impacts associates with the John Day MOP. Taking these effects our will lower the hydro savings since a year-round John Day MOP is included in the SOS Pa. These impacts are currently being examined by the Corps.

[2] Examples of structural combinations that could be utilized to improve transportation efficiencies.

In-River Path: Drawdown Sub-Path

Objective for Juvenile Passage

Drawdowns of the Lower Snake projects to natural river levels would eliminate project-related passage mortality and reduce juvenile travel time. Project drawdowns to spillway crest levels would lead to more modest improvements in juvenile travel times; survival benefits related to dam passage are uncertain, but may not improve.

Possible Sub-Paths

1. Permanent natural river drawdown at four pools (same as SOR alternative 5c);
2. Permanent natural river drawdown at two pools (Lower Granite and Little Goose);
3. Seasonal (four and one-half month) natural river drawdown at four pools (same as SOR alternative 5b);

4. Seasonal (four and one-half month) spillway crest drawdown at four pools (same as SOR alternative 6b);

5. Seasonal (four and one-half month) spillway crest drawdown at Lower Granite only (same as SOR alternative 6d).

General Description of Hydro System Operation

Under the natural river drawdown options the Lower Snake projects would be operated at or near natural river levels. Drafting for the four-and-one-half month drawdown (April 16 to August 31) would begin in February. The reservoirs would be operated within three to five feet of full pool the remainder of the year. Refill would be from natural inflows except in low water years when Dworshak would be drafted. Under the spillway crest option, the Lower Snake reservoirs would be drawn down to 33 feet below full pool. Drafting would begin April 1. Analysis completed by the Final SOR is used as a basis to measure the economic effects of drawdown. In the SOR the remainder of the hydro system, under both the spillway crest and the natural river drawdowns, is assumed to be managed similar to 1992 to 1993 operations. This operating strategy, however, is not likely to be incorporated into any future drawdown scenario. It is more likely that a drawdown operation would continue to include flow requirements similar to those specified in the 1995 Biological Opinion. Incorporating higher flow requirements in the drawdown operations is likely to significantly increase the related hydropower costs. These effects are currently under evaluation by the Corps.

Consideration of Economic Trade-Offs

The expected economic costs associated with the alternative drawdown operations are measured relative to current system operations as defined for this report. Cost figures are presented as average annual equivalents which take into account the differences in project on-line dates for the various drawdown options.

Construction Costs

Estimated construction costs and years required for project implementation vary considerably across the drawdown alternatives. The Seasonal Natural River Drawdown is significantly more expensive than any other drawdown option and would require at least 15 years to implement. The planning-level project construction costs, based on a 1996 price level, is estimated to be over $3.588 billion. The Permanent Natural River Drawdown is

accomplished by embankment removal and would require only five years for implementation. The option is expected to cost $533 million for design and construction at four projects. A Two Pool Permanent Natural River Drawdown of Lower Granite and Little Goose reservoirs is also possible, with estimated construction costs of $270 million. The Spillway Crest Drawdown also calls for significant modification to the existing Lower Snake projects, with the four-pool alternative requiring 10 years for implementation and $1 billion in construction costs. A One Pool Spillway Crest Drawdown at Lower Granite reservoir would require five years for implementation and would cost $79 million for design and construction.

Power Costs[9]

The power cost impacts associated with the Drawdown Sub-Path are primarily related to lost generation during the drawdown period (including reservoir evacuation and refill). Generation at the Lower Snake projects is permanently lost under the twelve month draw-

Table 8-4: Estimated Construction Costs Required for Drawdown, $1,000,000[10]

$1996 Cost Figures Drawdown Alternative	Years to Implement	Estimated Project Costs[1] Total	Annual Equivalent
PERMANENT NATURAL RIVER			
Four Pool	5	$543	$36
Two Pool	5	$271	$18
SEASONAL NATURAL RIVER			
Four Pool	15	$3,588	$168
SEASONAL SPILLWAY CREST			
Four Pool	10	$1,033	$57
One Pool	5	$79	$5

Source: System Configuration Study, Phase 1, Appendix A, Lower Snake Drawdown Options Technical Report. Updated to $1996.

1 Total costs do not include interest during construction. Annual project costs include annualized construction costs (including interest during construction) and annual O&M.

9 Power costs estimates for the drawdown alternatives currently include power impacts related to drawdown of the John Day reservoir to MOP. This reservoir operation has been removed from consideration in the Lower Snake Path Analysis. The power cost analysis prepared for the SOR is currently being revised by the Corps of Engineers (North Pacific Division) to remove this operation. Estimates should be available during September 1996 and will be incorporated into the economic analysis at that time. The draft estimates provided in this document include impacts related to the John Day MOP.

10 A more detailed description of construction costs for the Lower Snake drawdown options is presented in Appendix C, Economic Costs.

down option. Under the seasonal natural river alternative, generation at the projects is no longer possible when pool elevations drop fifty feet below normal operation pools (a drawdown of approximately one hundred feet is required to reach natural river levels). The seasonal drawdown would decrease average annual energy production by 520 average megawatts (aMW) relative to current system operations while the permanent drawdown would lead to a decline in production of 640 aMW. Although power generation losses under the seasonal drawdown are approximately 85 percent of losses under the permanent drawdown, the average annual equivalent power costs are significantly less. This is due, in part, to the much longer implementation period required for the seasonal drawdown. The lower costs also result because generation losses for the seasonal drawdown do not have to be replaced during the more expensive winter period. It should be noted that the longer implementation periods associated with the seasonal natural river drawdown result not only in delayed economic costs but also in delays in achieving the desired fish goals.

The relatively high power costs associated with the base case operations for this report are exceeded only by the power costs related to the Permanent Natural River Drawdown. Power costs related to the permanent drawdown increase by $25 million annually relative to current operations while the Seasonal Natural River Drawdown results in a decline in annual power costs of $69 million.[11]

Hydro system operations under both the four pool and one pool spillway crest drawdowns would lead to increases in annual energy production relative to current conditions. Regional power costs for the four pool and one pool drawdowns would decline by $92 million and $102 million, respectively.

Recreation Costs

The recreation impacts related to drawdown are associated almost exclusively with the reductions in visits to the Lower Snake projects where drawdown occurs. The losses in recreation values on the Lower Snake are compensated somewhat by increased visitor levels at Grand Coulee and Dworshak reservoirs. Under current operations however, these latter two reservoirs are drafted to meet flow augmentation requirements, resulting in lower pool elevations during the spring and summer season.

Declines in recreation visits under the Seasonal Natural River Drawdown are nearly twice those under the Spillway Crest Drawdown (relative to current operations). However,

[11] Power cost estimates for the two pool permanent natural river drawdown are also under current evaluation by the Corps and should be available during Fall 1996. The estimates will be incorporated into the decision analysis at that time.

because the Seasonal Natural River Drawdown requires fifteen years to implement compared to ten years for the spillway crest drawdown, the decline in recreation visits occurs sooner with the latter alternative. Recreation losses are valued at $23 million annually for the natural river option and $17 million for the spillway drawdown.

Expected losses in recreation values are very similar under the seasonal and permanent natural river drawdowns (the partial year drawdown coincides with the peak recreation season). Expressing recreation impacts in terms of average annual equivalents has the effect of diminishing the relative impacts under the seasonal drawdown since actual losses are not assumed to begin for an additional 10 years after implementation of permanent drawdown. Annual losses for the permanent drawdown are estimated at $58.6 million for the four pool alternative and $33 million for the two pool option.[12]

Additional Recreation Benefits

The most significant losses in recreation values were found to occur with the permanent natural river drawdown of the four Lower Snake projects. Under this alternative, a new river bypass would be created around the project facilities, restoring the natural river segment along the Lower Snake River. The estimated recreation impacts for this alternative do not take into account the new recreation opportunities that would be made available with the restoration of natural river conditions. The economic values associated with the natural river recreation would likely compensate for a portion of the reservoir losses under the permanent drawdown.

The recreation impacts measured for the present study are taken from the comprehensive recreation analysis conducted for the Columbia-Snake River System Operation Review (SOR). Recreation impacts developed for the SOR reflect the values that individuals place on the variety of reservoir recreation experiences provided by the Columbia-Snake project facilities. Operational changes which result in a decline in the availability or quality of these recreation experiences lead to a decline in the values associated with the project reservoirs. While these values are lost to the Columbia-Snake River system, the entire value may not be lost to the individual or to the region. It is likely that with reservoir recreation unavailable, individuals would seek out a "next best" recreation alternative. Taking into account these non-reservoir alternatives was beyond the scope of the SOR analysis.

12 A five year implementation period is assumed for the two pool permanent drawdown. A more rapid implementation of the two pool drawdown would increase the comparative costs of this alternative, since the resource costs associated with the operation would be assumed to occur more quickly.

Navigation Costs

Drawdown of the Lower Snake reservoirs prevents access to the locks necessary to allow commercial barge traffic to move from one reservoir to the next. The locks are inaccessible for seven months out of the year under the seasonal natural river drawdown and for five months out of the year under the spillway crest drawdown. The locks are no longer accessible under permanent drawdown. The two pool permanent drawdown is expected to have similar impacts to the four pool option since nearly all of the Lower Snake port facilities are located in the Lower Granite and Little Goose pools. Incremental navigation costs for the drawdown alternatives range from $33 million annually under permanent drawdown to less than $2 million with the spillway crest drawdown at Lower Granite only.

Avoided Cost Issues

A rehabilitation study is currently underway for the generating units at the Ice Harbor project. Several options are currently being evaluated, including the installation of fish friendly turbine runners. Preliminary estimates for the Ice Harbor rehab are not currently available but are expected by Fall 1996. The study is expected to be completed by Spring 1997 with potential implementation of study recommendations to begin within the following two to three years. Rehab studies are not currently under evaluation for the other Lower Snake projects, but could be expected sometime within the next ten to fifteen years. A permanent drawdown of the Lower Snake reservoirs would obviate the need for continued upgrades to the projects, since they would no longer be operable. The extent to which these cost savings would offset the economic costs associated with the Permanent Drawdown will depend on the time frame for actual implementation. Annual maintenance requirements at Ice Harbor currently exceed budgeted O&M allowances. If drawdown is delayed for several years and the rehab is not scheduled, significantly higher annual operating costs will be incurred at the project. Estimates of these cost issues have not been developed in detail and are beyond the scope of the present study.

A permanent drawdown of the Lower Snake reservoirs may also result in potential reductions in funding levels in the current regional anadromous fish program that may result with long-term implementation of alternative downstream passage strategies. Potential reductions in the Corps of Engineers' research, monitoring, testing, and evaluation programs may also occur. The Corps budget for this program is estimated at $568 million for the next six years. Details of these potential cost savings are beyond the scope of the present study.

Other Issues

Reservoir drawdowns will affect irrigation and municipal/industrial water supply pumping on the Lower Snake. Pumps in all four pools will need to be extended in order to maintain pumping during the drawdown period. Annual operating costs will also increase, reflecting the higher energy costs required to lift water from the lower pools. Average annual equivalent costs related to irrigation and water supply pumping range from $0.3 million for a spillway crest drawdown at Lower Granite only to $3.8 million for a four-pool permanent natural river drawdown. These impacts have been incorporated as mitigation costs in the overall estimates for project implementation.

Summary of Economic Trade-Offs

The economic costs associated with various options for the Drawdown Path are summarized below in Table 8-5. These figures can be reviewed in conjunction with the biological and engineering information to determine a preferred drawdown strategy.

Table 8-5: Annual Economic Costs for Alternative Drawdown Operations, $1,000,000

Average annual equivalents in 1996 dollars, measured as changes from Current Operations

Drawdown Alternative	Total Costs	Construction Costs[1]	Power Costs[2]	Recreation Costs	Navigation Costs
PERMANENT NATURAL RIVER					
Four Pool Drawdown	$153	$36	$25	$59	$33
Two Pool Drawdown	$109[2]	$18	N/A[3]	$33	$33
SEASONAL NATURAL RIVER					
Four Pool Drawdown	$130	$168	($69)	$23	$8
SEASONAL SPILLWAY CREST					
Four Pool Drawdown	($9)	$57	($92)	$17	$9
One Pool Drawdown	($81)	$5	($102)	$14	$2

[1] Water supply impacts are included as mitigation costs in the cost estimates presented for project implementation. See Appendix C for more detail.

[2] Power costs still include the impacts associated with the John Day MOP. According to BPA, this is a large component of the costs under the SOR preferred alternative (used to represent current operations). Removing these impacts will adjust the relative power costs between alternatives. These costs are currently being examined by the Corps.

[3] For purposes of display, power cost changes for the two pool drawdown are estimated to be the same as the four pool drawdown. Actual power costs are likely to be less. Figure will be revised when power cost estimates are completed by the Corps.

Delayed Implementation of Permanent Drawdown

Economic costs for the permanent drawdown have been measured assuming that a five-year time period would be necessary for implementation of the strategy. This interval is based on the time required for project design, engineering, and construction. Delayed implementation of the permanent drawdown for five or even ten years would significantly lessen the annual equivalent costs associated with the alternative, perhaps by as much as one-third to one-half. For example, delaying implementation by ten years would reduce annual equivalent construction costs from $36 million to under $20 million. Significant reductions in the annual equivalent costs related to power and recreation would also be measured. Actual costs at the time of implementation would, of course, remain unchanged; system generation losses would average approximately 640 aMW annually and the Lower Snake reservoirs would no longer support navigation or flat-water recreation.

However, delayed implementation of this alternative has been suggested in some regional forums as an effective means by which the region could mitigate the adverse economic and programmatic impacts associated with permanent dam removal. A planning period of five to ten years would provide the region with an opportunity to revise recovery and mitigation programs to take full advantage of the permanent drawdown operation and to minimize adverse power generation impacts.

In-River Path: Non-Drawdown Sub-Path

Objective for Juvenile Passage

The primary objective of the *In-River Path* is to improve downstream survival through improved juvenile bypass systems, improved spill operations and reduced turbine mortality. The path goal is to achieve an 80 percent FPE at the Lower Snake projects with a combination of structural improvements. Increased flows are also provided to reduce juvenile travel time through the reservoirs. Juveniles would not be transported under this path, regardless of water conditions and flow levels.

Current Operations Strategy

NMFS has established a flow target of 85 to 100 kcfs at Lower Granite Dam between April 16 to June 20 to achieve an 80 percent FPE at the Lower Snake projects. When

flows exceed 100 kcfs, spill occurs at all projects; when flow falls between 85 and 100 kcfs no spill occurs at Lower Granite; and when average flows fall below 85 kcfs no spill occurs at Lower Granite, Little Goose, or Lower Monumental. Summer spill occurs only at the Ice Harbor project. Spill is limited to twelve hours per day, during the night time period.

To meet an 80 percent FPE at the Lower Granite, where the current bypass system includes extended length screens, approximately 31 percent of the targeted flow of 100 kcfs, or 31 kcfs, must be diverted through the spillway with the remainder passing through the turbines. Under this regime, approximately 31 percent of the fish pass over the spillway and 70 percent of the remaining fish (70 percent of 70 percent) are guided into the collection system, resulting in 80 percent of the fish diverted away from the turbines.

Possible Sub-Path Alternatives to Achieve a Project FPE of 80 Percent

A variety of strategies can be utilized to improve fish passage efficiencies at the Lower Snake projects, including improvements to existing juvenile bypass systems or improvements to current spill operations. The economic costs associated with several of these options are outlined below.

1. Spill Operations
   a. Current spill operations as required under the 1995 Biological Opinion;
   b. Current spill operations with mitigation for high TDG concentrations;
   c. Spillway baffles with optimistic fish-spill ratios (20:1) requires a $1^1/2$ percent spill;
   d. Spillway baffles with realistic fish-spill ratios (10:1) requires a three percent spill;
   e. Spillway baffles with pessimistic fish-spill ratios (5:1) requires a six percent spill.

2. Juvenile Bypass System Improvements
   a. Unscreened surface collectors at one, two, or three projects (LGR, LGO, LM);
   b. Installation of sluices as an alternative to surface collectors (LGR, LGO, LM);
   c. Extended-length screens at one or two projects (LM, IH);
   d. Various project combinations with spill, surface collectors, sluices, and extended length screens.

Consideration of Economic Trade-Offs

The economic trade-offs between spill operations and bypass system improvements can be examined by looking at differences in annualized system costs under the various sub-path options to achieve 80 percent FPE at the Lower Snake projects. The hydro system is assumed to be operated similar to the base case conditions defined for this report, including the Columbia and Snake River flow targets established in the 1995 NMFS Biological Opinion and incorporated into the SOR preferred alternative. Consequently, the primary economic costs associated with the *In-River: Non-Drawdown Path* will be related to construction costs for system improvements and power cost impacts for options with and without spill operations.

Spill-Related Improvements

Current spill operations pass approximately one percent of juvenile fish through the spill bays for every one percent of project flow diverted to the spillways. The installation of baffles in the spillway bays could potentially lead to significant increases in fish guidance efficiencies for the spill operation. Estimates for baffled spill effectiveness range from 20 to five percent of fish passed per one percent of flow directed over the spillway. Total construction costs for a spillway baffle are estimated to be $500,000 for each bay in which a baffle is installed.[13] Construction could be completed within a year, leading to an average annual equivalent cost of $37,000 per baffle. An optimistic fish-spill (20:1) scenario would require installation of one baffle to achieve a 30 percent FPE for spill. Alternative fish-spill ratios of (10:1) and (5:1) would require installation of two and three baffles, respectively, to achieve a 30 percent project FPE for spill.

Results of current testing programs may conclude that the total dissolved gas (TDG) concentrations associated with spill levels of 30 percent are unacceptable for fish survival, requiring mitigation investments. These costs would be additive to the current operations. As an example, Phase I of the SCS identified elevated stilling basins as a possible option for lowering the TDG concentrations associated with spill. Construction costs for the design and construction of the elevated basin are estimated to be $38 million. Six and one-half years would be required for implementation, resulting in an average annual equivalent cost of $2.35 million.

[13] Cost estimates for spillway baffles obtained from Harza.

Juvenile Bypass System Improvements

Surface collectors, sluices, or extended-length screens could be used singly or in combination to improve fish passage efficiencies at the Lower Snake projects. Construction costs for a full-scale surface collector that could be used for transportation collection as well as bypass are estimated to be $25 million. However, an unscreened version of the collector could be used for the exclusive in-river strategy since collection for transport is not required. The estimated construction costs for an unscreened surface collector are $18.7 million.[14] Three years would be required for project implementation, resulting in an annual equivalent cost of $1.4 million. Construction costs for sluices and extended-length screens would be the same as those described for the full *Transportation Path* with average annual equivalent costs of $0.8 million for a sluice and $1.8 million for extended-length screens.

Implementation Costs for Multiple Projects

The Biological Opinion requires an 80 percent FPE at each of the four Lower Snake projects. Decisions regarding whether to continue with current spill operations or whether to adopt a modified spill operation or to make improvements to juvenile bypass systems must be made at each of the projects. Total implementation costs for the *In-River Path* will depend on the most cost-effective combination of strategies selected to meet the 80 percent FPE goals while maintaining low gas concentrations.

Table 8-6: Implementation Costs for Multiple Project Investments, $1,000,000

Average annual equivalents in 1996 dollars, measured as changes from Current Operations

Structural Improvement	Number of Projects 1	2	3	4
Spill only (1995 BiOp)	$0.0	$0.0	$0.0	$0.0
Spill with mitigation	$2.4	$4.8	$7.2	$9.6
Spillway Baffles				
One Baffle	$0.04	$0.08	$0.12	$0.16
Two Baffles	$0.08	$0.16	$0.24	$0.32
Three Baffles	$0.12	$0.24	$0.36	$0.48
Surface Collector	$1.4	$2.8	$4.2	$5.6
Sluice	$0.8	$1.6	$2.4	$3.2

[14] Personal Communication, Corps of Engineers, Walla Walla District, June 1996.

Power Costs

Reducing spill requirements allows more flow to pass through the powerhouse, increasing hydropower generation which may then be used within the region to displace more expensive power resources or may be sold outside the region under short-term contracts. Baffled spillways could significantly reduce the amount of spill necessary to meet targeted fish passage goals, thereby reducing the hydropower losses associated with the operation. The system-wide power losses associated with alternative spill operations are currently being developed by the Corps.[15] When the estimates become available they will enable a more complete examination of the economic trade-offs between bypass system improvements and spill operations.

The hydraulic requirements for a surface collector installed at a Lower Snake project are expected to range from 8,000 to 12,000 cfs; a sluice would require 3,000 cfs for operations.[16] The power cost impacts related to the utilization of these bypass improvements would depend on the number of projects where these devices were installed, and the associated average annual flows. System-wide power impacts related to these improvements are also currently being evaluated by the Corps.

Minimum Operating Pools at the Lower Snake Dams

Under current operations of the hydro system, the Lower Snake reservoirs are drawn down to minimum operating pool during the spring and summer period. An in-river strategy which excludes the MOP operation will result in economic impacts in addition to those identified for the spill operations and bypass improvements. Estimates prepared by BPA have suggested that the current cost of the Lower Snake drawdown to MOP, in terms of lost power revenues, is approximately $20 million.[17]

Flow Targets Under Current Operations

Under current operations of the hydro system, the spring and summer flow targets have been established for the Snake and Columbia rivers.[18] Snake River targets are measured at

[15] The hydropower costs associated with alternative project spill levels are currently being examined by the Corps and should be available sometime during Fall 1996.

[16] Personal Communication, Corps of Engineers, Walla Walla District, June 1996.

[17] Estimate from BPA's Dittmer Operations, June 1996. Additional studies of the hydropower losses associated with alternative specifications for Columbia and Snake River flow targets are currently under evaluation.

[18] Spring refers to the period from April 16 to June 20 while summer is measured from the period June 21 to August 31.

Lower Granite; spring flow targets range between 85 and 100 kcfs, based on sliding scale linked to run-off forecasts. The summer flow target ranges from 50 to 55 kcfs, also linked to a sliding scale. Columbia River flow targets are established at McNary Dam and are based on run-off forecasts measured at The Dalles. Spring flow targets on the Columbia are linked to a sliding scale with upper and lower bounds of 260 and 220 kcfs, respectively. The summer flow target is fixed at 200 kcfs.

It is estimated that the current flow targets on the Snake and Columbia Rivers require an additional eight million acre-feet (MAF) to be released from up-river storage. This water must be held in storage during fall and winter to ensure that sufficient supplies are available for release during spring and summer. Because the water must be held in storage, economic losses occur as a result of foregone hydropower generation in the fall and winter. BPA estimates that the value of these hydropower losses is equivalent to approximately $10 million per one MAF that must be held in storage for later spring and summer releases. The total value of hydropower losses associated with the eight MAF allocated to meet fish flow targets is $80 million.[19]

Other Issues

Navigation and irrigation and M&I water supply would be unaffeted by the alternative strategies examined for the *In-River, Non-Drawdown Sub-path.*

Summary of Economic Costs

For purposes of comparison, single project estimates are made of the trade-offs between spill operations with and without baffled spillways and with and without mitigation for high concentrations of dissolved gases. A cost comparison is also made for selected bypass improvements.[20] The project specific comparison assumes flows of 100 kcfs from April 16 through June 20 and flows of 55 kcfs from June 21 to August 31. The evaluation provides only a preliminary comparison between the various options to improve FPE. A system-wide comparison is also important so that the cost effectiveness of the alternative operations can be examined for the range of water years in the historical record. These costs are currently being estimated by the Corps of Engineers and will be made available Fall 1996.

[19] The economic costs for the *In-River Path* will be revised when the final power cost estimates become available this fall.

[20] Power costs for the surface collector are estimated using a mid-range hydraulic capacity of 10,000 cfs.

Table 8-7: Individual Project Costs for Alternative FPE Improvements, $1,000,000

Average annual equivalents in 1996 dollars

Potential Improvement	Total Costs	Construction Costs	Power Costs
SPILL OPERATIONS			
Current 31 percent Spill	$2.70		$2.7
31 percent Spill with TDG Mitigation	$5.10	$2.4	$2.7
Baffles with (20:1) Fish-Spill	$0.24	$0.04	$0.2
Baffles with (10:1) Fish-Spill	$0.56	$0.08	$0.4
Baffles with (5:1) Fish-Spill	$0.91	$0.11	$0.8
JUVENILE BYPASS IMPROVEMENTS			
Surface Collector	$5.0	$1.4	$3.6
Sluice	$1.9	$0.8	$1.1
Extended-Length Screens	$1.8	$1.8	$0.0

Summary of System-Wide Impacts

The system-wide impacts for possible sub-paths under the *In-River Path* are summarized below.[20] The sub-paths represent alternative combinations of structural improvements and spill operations that could be used to achieve 80 percent FPE for the Lower Snake projects. Flow targets for the alternative sub-paths are assumed to be the same as those for current operations. Alternative specifications for the flow targets would result in significant changes to the hydropower costs associated with the *In-River* sub-paths.

Mixed Path

Objective for Juvenile Passage

The primary objective of the *Mixed Path* is to improve downstream survival through a combination of improvements to juvenile bypass and collection systems, improved spill operations, and utilization of the Corps' Juvenile Transportation Program. The path goal is to achieve an 80 percent FPE at the Lower Snake projects; this is the same goal established for the *In-River Path*.

Table 8-8: Annual Economic Costs for Alternative In-River Strategies, $1,000,000

Average annual equivalents in 1996 dollars, measured as changes from Current Operations

Subpath Alternative	Total Costs	Construction Costs	Power Costs[a]
SPILL OPERATIONS			
Current Spill (*4 projects*)	$0.0		$0.0
with TDG mitigation	$9.6	$9.6	$0.0
Baffled Spill (20:1) (*4 projects*)	($9.84)	$0.16	($10.0)
Baffled Spill (5:1) (*4 projects*)	($7.16)	$0.44	($7.6)
JUVENILE BYPASS IMPROVEMENTS			
Surface Collector (*1 project*)	$2.3	$1.4	$0.9
Surface Collector (*2 projects*)	$4.6	$2.8	$1.8
Surface Collector (*3 projects*)	$6.9	$4.2	$2.7
Surface Collector (*4 projects*)	$9.2	$5.6	$3.6
Sluice (*1 project*)	($0.8)	$0.8	($1.6)
Sluice (*4 projects*)	($3.2)	$3.2	($6.4)
S.C. & Screens (*1 project/2 projects*)	$5.9	$5.0	$0.9
S.C. & Screens (*3 projects/1 project*)	$8.7	$6.0	$2.7

[a] Costs will be revised when Corps estimates of system power impacts are completed in Fall 1996.

Possible Sub-Path Alternatives

1. Current operations of the Lower Snake under the NMFS Biological Opinion.
2. Combination of juvenile transportation with recommended structural improvements from the *In-River Path*.

Consideration of Economic Costs

The economic costs for current system operations under the Biological Opinion have been estimated at $125.5 million (relative to system operations in 1992-93). Costs related to the *Transportation*, *Drawdown*, and *In-River* paths have been estimated relative to the current mixed strategy operation.

Economic costs for a mixed strategy that includes bypass improvements or modified spill operations will be similar to those identified for the *In-River Path*, ranging from an increase in average annual equivalent costs of $9.6 million for a strategy based on current spill operations but including investments to mitigate for high gas levels to a savings in annual economic costs of $7 to $10 million dollars for the installation of spillway baffles at all four Lower Snake projects.

The most significant impact of alternative *Mixed Path* options on economic costs would occur with the adjustment of flow targets on the Snake and Columbia Rivers. BPA estimates the value of power losses associated with spring and summer fish flow augmentation is valued at $10 million per one MAF released from storage.

Section 9

DECISION PATH ANALYSIS

Section 9 DECISION PATH ANALYSIS

Decision Analysis

The region and agencies responsible for management of the Lower Snake hydro system have invested millions of dollars in structures and research oriented towards protection and recovery of salmon. Many physical and operational alternatives have been proposed with differing expectations for outcomes. Although some alternatives could be implemented in combination, many are mutually exclusive. Many also require considerable investment and have varied impacts across the region. To further complicate matters, the studies and proposals to date have not been coordinated or evaluated on a comparable basis. There is also considerable risk and uncertainty associated with many of the options.

The application of decision analysis provides an opportunity for decision makers and the public to consider the alternative actions that can be applied to the Lower Snake hydro system. The purpose of decision analysis is to organize alternative actions in a logical manner that allows consistent comparisons with a baseline, while explicitly considering the risks and uncertainties associated with each outcome as a part of the decision process. The approach has two other important properties:

1. The construct is independent of the evaluation criteria, so that differing objectives and decision criteria can be evaluated using the same structure.
2. The decision structure is dynamic, providing a means of incorporating new information as it becomes available.

Decision Tree

The central feature in the application of decision analysis is the *decision tree*. A decision tree is a graphical and analytical representation of the combination of management decisions and potential outcomes from such actions. The "tips" of the branches represent

possible outcomes, measured in comparable units. Associated with each of the potential outcomes are expected probabilities of that outcome occurring. With all possible outcomes characterized by well-defined probabilities, the tree may be used to evaluate the path which best meets the specified objective.

The decision tree consists of all anticipated permutations of management actions and facilities. Each individual action results in set of possible outcomes which may be characterized by a distribution function containing a mean value and range. These values are the combined joint probabilities associated with outcomes for individual activities or actions.

Construction of the tree requires the following components:

1. **Selection of relevant management actions and facilities.** The tree should contain those paths which will *actually* be considered.

2. **Selection of the primary units of measure by which to compare alternatives.** This measure could be, for example, juvenile survival rate. Other criteria, such as cost, may play a role in the evaluation or elimination of paths.

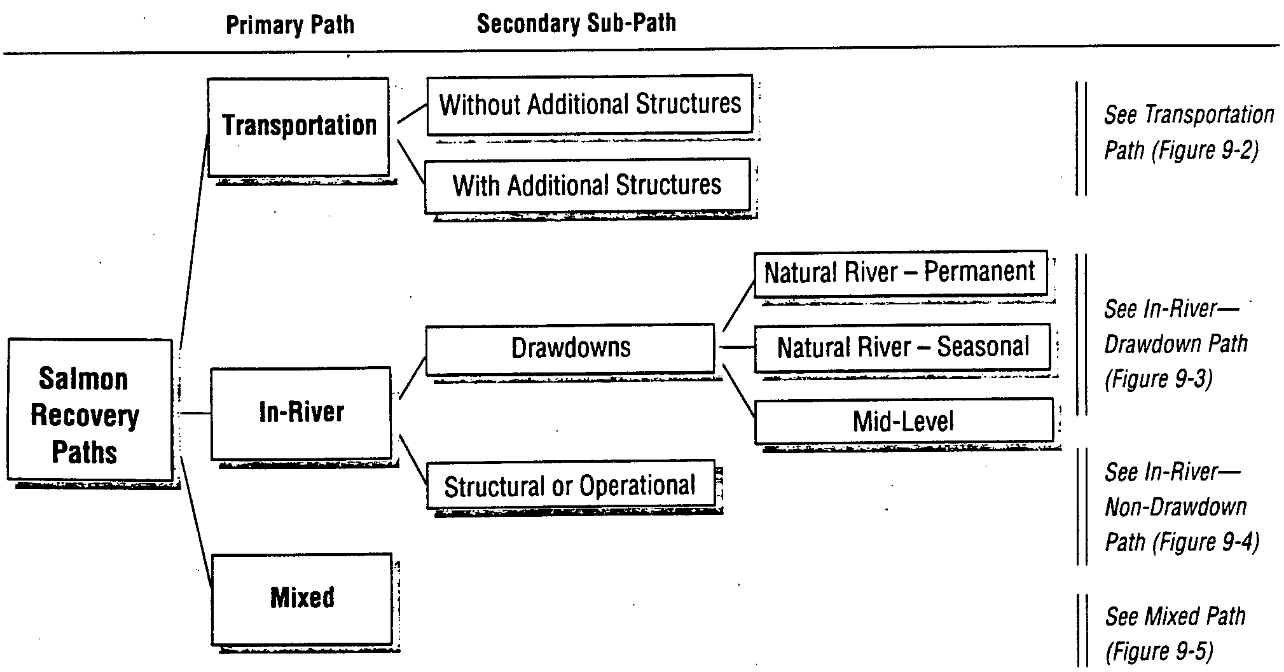
3. **Identification of the value of potential outcomes, combined with a characterization of the probabilities associated with that outcome.** Of course, some outcomes are not known or can only be conjectured. The level of "comfort" or degree of uncertainty with those numbers will be considered in the assessment. "Outcomes" are defined in biological, economic, or social terms. For example, biological terms would include fish passage efficiency (FPE), juvenile survival, or smolt-to-adult-return rate (SAR).

4. **Notation of a qualitative ranking on the relative "firmness" of the outcomes and probability distributions.** In other words, is there an empirical basis for suggesting the outcomes, or is experimentation or measurement required? These qualifications will be carried through the analysis.

Description of the Primary Paths

The central decision facing the region is the selection among three paths: 1) full or exclusive *Transportation*; 2) some form of *In-River* juvenile migration; or 3) a *Mixed* or combination of transportation and in-river (see Figure 9-1). Each of these primary paths contains sub-paths reflecting alternative actions and combinations of actions.

Figure 9-1: Lower Snake River System Decision Tree



In theory, the decision paths could include all possible combinations of actions. However, some of the combinations were eliminated as a result of functional redundancy or earlier research. As a consequence, the study team examined existing information and developed a set of paths that reflects relevant outcomes.

Transportation Path

The *Transportation Path* ultimately reflects a regional decision relying on transportation for salmon recovery. Inherent in this path are several improvement commitments already made to reduce transport stress and fish mortalities. These include:

- the direct loading of barges;
- reductions in loading densities; and
- modification in barge release mechanisms.

At present, the NMFS BiOp provides spill of 10 to 80 percent, depending upon flow levels. This program allows as many as 50 percent of juvenile spring chinook to be trans-

ported from Lower Granite. An additional 15 to 20 percent can be transported from Little Goose and Lower Monumental, to below Bonneville Dam. The *Transportation Path* goal would be to collect 90 percent of migrants arriving at Lower Granite. Decisions are required as to whether transportation should continue at Little Goose and Lower Monumental (see Figure 9-2).

The juveniles not collected at Lower Granite would pass down river via turbines or uncontrolled spill. Additional decisions are thus required as to whether surface bypass/collectors will be added to the Lower Snake dams and other dams down river. These structures will protect the relatively small number of juveniles continuing downstream. Similarly, investment decisions are necessary regarding extended-length barrier screens (ESBS) at Lower Monumental, Ice Harbor, or both. Screens are already in place at Lower Granite and will be installed at Little Goose in 1997.

Outcomes for each branch reflect the combination of transport from one to three sites, with additional structures, if any. Economic cost is defined as the additional cost above existing methods; thus, transport with no additional structures or changes in hydro system operations has no marginal investment or hydropower cost.

In-River Path

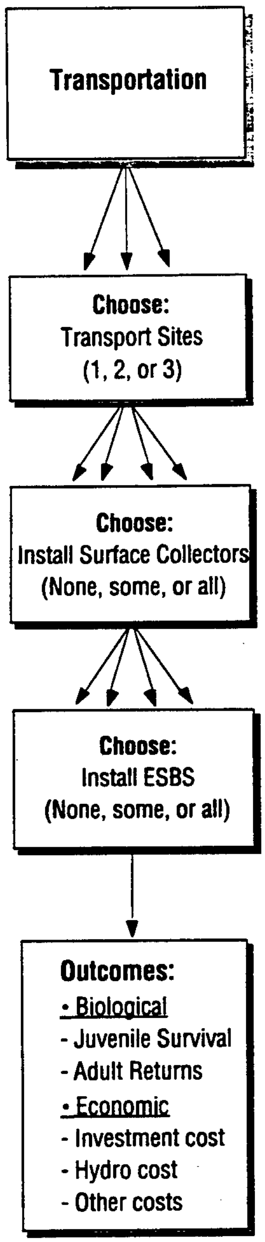
The *In-River Path* reflects a decision that relies on in-river migration of juveniles. Two sub-paths branch immediately from the *In-River Path*: one relying on some form of drawdown (including embankment removal), and the other sub-path with dams in place involving non-drawdown structural, the latter could include transportation during drought or flood conditions.

Drawdown Sub-Path

The *Drawdown Sub-Path* considers three major types of drawdown (see Figure 9-3):

1. *Natural River* (permanent) *Drawdown*, using embankment removal, for two pools (Lower Granite and Little Goose) or four pools;
2. *Natural River Seasonal* ($4^1/_2$-month) *Drawdown*, for all four pools; and
3. *Seasonal* ($4^1/_2$-month) *Drawdown* near spillway crest, for one pool (Lower Granite) or four pools.

Figure 9-2: Transportation Path



Transportation can be conducted ...

From 1, 2 or 3 sites ...

With or without surface bypass/collectors, or some combination ...

and with or without the addition of extended-length submerged screens ...

Which results in a set of outcomes addressing biological, economic, or other criteria.

Based upon your objective, you can:
- —Prune unacceptable paths
- —Retain paths that might satisfy your objective, based on new data, or
- —Select a single path as superior.

The permanent drawdown options would involve removing embankments, and thus remove any structural impediment to migrating juveniles. Hydropower generation would cease at those sites, and the projects (two or four) would be bypassed with flows.

For the other two seasonal drawdown options, hydropower generation could continue during the non-drawdown period (October 1 through February 15) when the reservoirs would be operated within three to five feet of full pool. It is possible, therefore, to consider the investment in surface bypass/collectors at non-drawn down dams and/or extended length screens on the two lower dams to accommodate juveniles in the non-drawdown period.

Non-Drawdown (Structural or Operational) Sub-Path

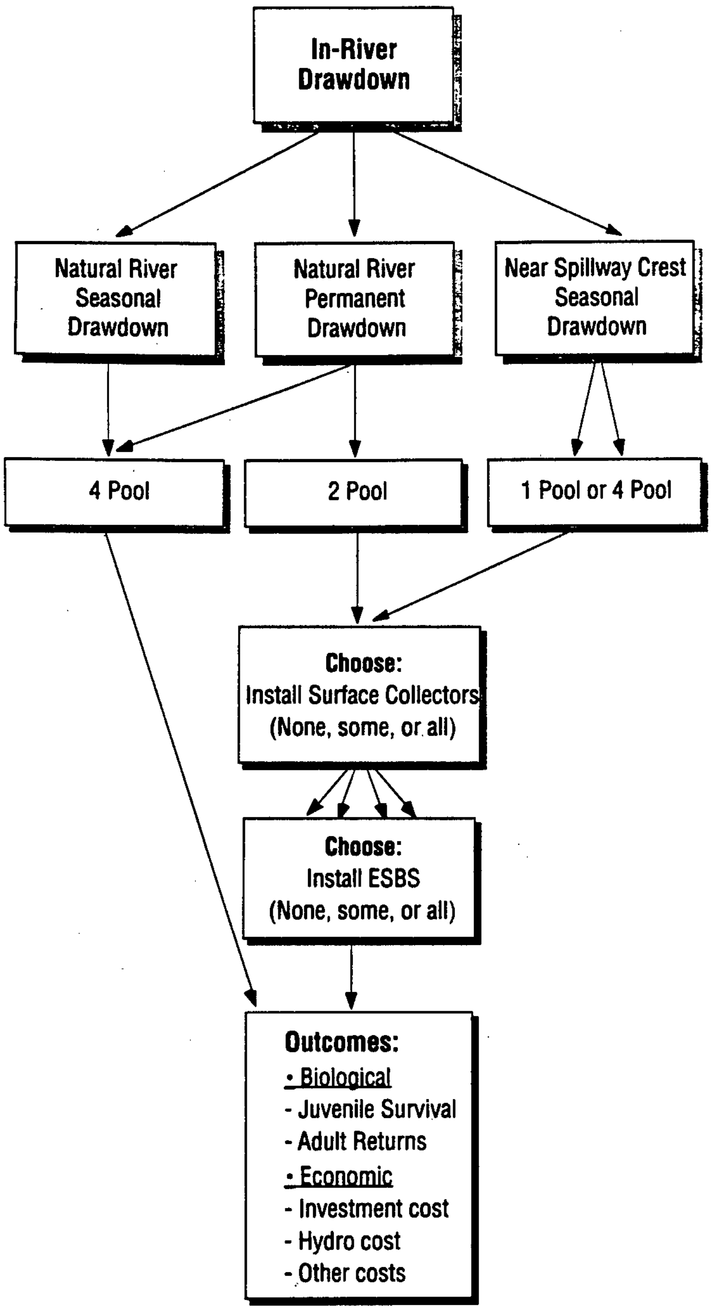
The non-drawdown path relies on in-river solutions that do not involve drawdown. The two types considered would use spill in combination with new or existing structures, or use new or existing structures without spill (see Figure 9-4). New structures considered in combination with spill are surface bypass/collectors and extended length screens, and investment decisions in stilling basin modifications and turbine improvements. In essence, the spill option could include any combination of the above structures, which could reduce problems of nitrogen supersaturation or aid in guiding juveniles away from turbines.

The other non-drawdown, spill option would consider the installation of spillway baffles, the addition of surface bypass/collectors, and installation of extended length screens on the lower projects. In particular, investment decisions may be made on any combination of baffles, large surface bypass/collectors, or smaller sluices on all projects, and the addition of extended length screens on Lower Monumental and/or Ice Harbor.

Mixed Path

The *Mixed Path* involves the use of *Transportation* with *In-River* solutions. This could involve spilling at strategic times and when flows are adequate. It differs from the other two main branches in the level of emphasis placed on the options. The *Mixed Path* attempts to maintain a balance between transportation and keeping fish in the river, as a means of "spreading the risk" associated with the respective solutions. This is in contrast to the full *Transportation Path*, which emphasizes transport of as many fish as practical, while perhaps supplying additional structural improvements to guide the remaining fish from the turbines. The *Mixed Path* is also different from the *In-River Path* by not involving drawdown and by including a concentrated program of transporting a minimum number of juveniles annually.

Figure 9-3: In-River—Drawdown Path



The **In-river, drawdown options** include ...

1) **Natural River Permanent Drawdown** with embankment removal
   a) 2 pool (LGR and LGO), or
   b) 4 pool

2) **Natural River Seasonal Drawdown** on the four Lower Snake Projects, during a 4 1/2 month operating period

3) **Seasonal Drawdown near spillway crest** during a 4 1/2 month operating period
   a) 2 pool (LGR and LGO), or
   b) 4 pool

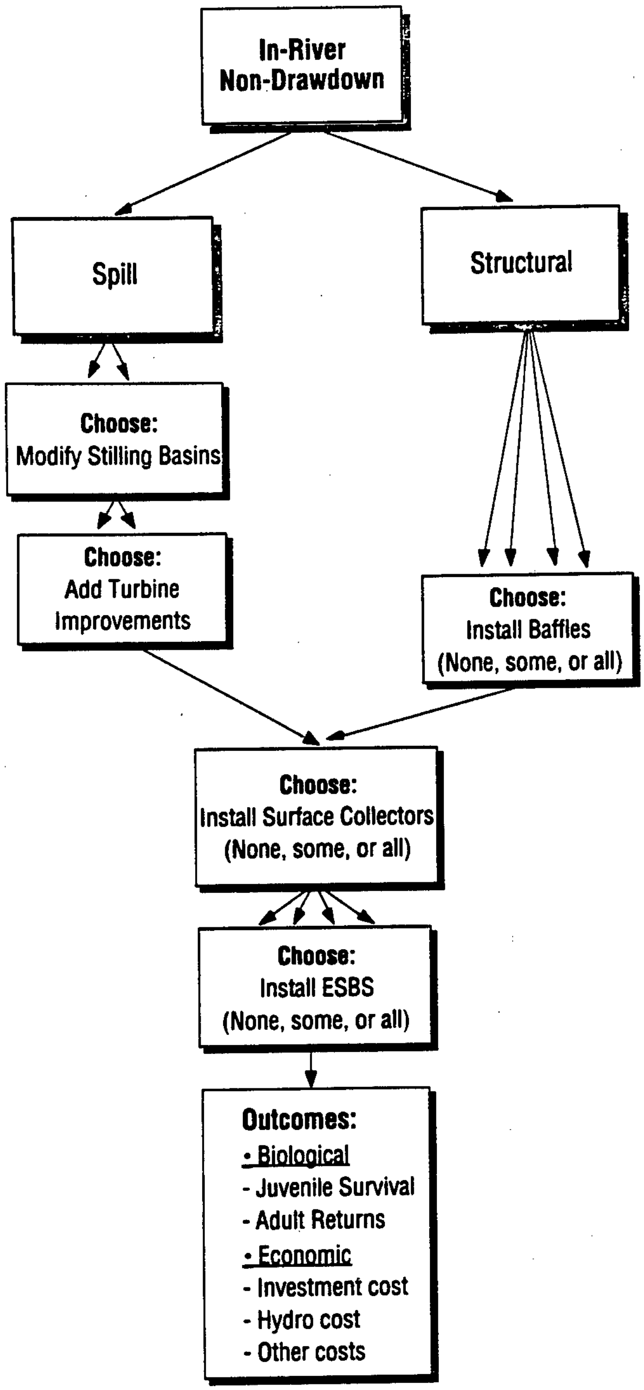
With or without surface bypass/collectors, or some combination ...

and with or without the addition of extended-length submerged screens ...

Which results in a set of outcomes addressing biological, economic, or other criteria.

Based upon your objective, you can:
—Prune unacceptable paths
—Retain paths that might satisfy your objective, based on new data, or
—Select a single path as superior.

Figure 9-4: In-River—Non-Drawdown Path



The **In-river, non-drawdown** options include:

1) use of spill, or
2) use of structural improvements only

1) Spill may be used ...

   a) With or without stilling basin modifications; and
   b) With or without turbine improvements

2) Structural (non-spill) improvements may include ...

   a) Installing baffles at some or all sites

Both non-drawdown options include considering ...

installation of surface bypass/collectors ...

and with or without the addition of extended-length submerged screens ...

Which results in a set of outcomes addressing biological, economic, or other criteria.

Based upon your objective, you can:
—Prune unacceptable paths
—Retain paths that might satisfy your objective, based on new data, or
—Select a single path as superior.

The *Mixed Path* has two main branches: one involving spill combined with transportation, and the other using structural improvements and operational changes (excluding spill) in combination with transportation (see Figure 9-5). The former is consistent with current Lower Snake operations, or NMFS 1995 Biological Opinion.

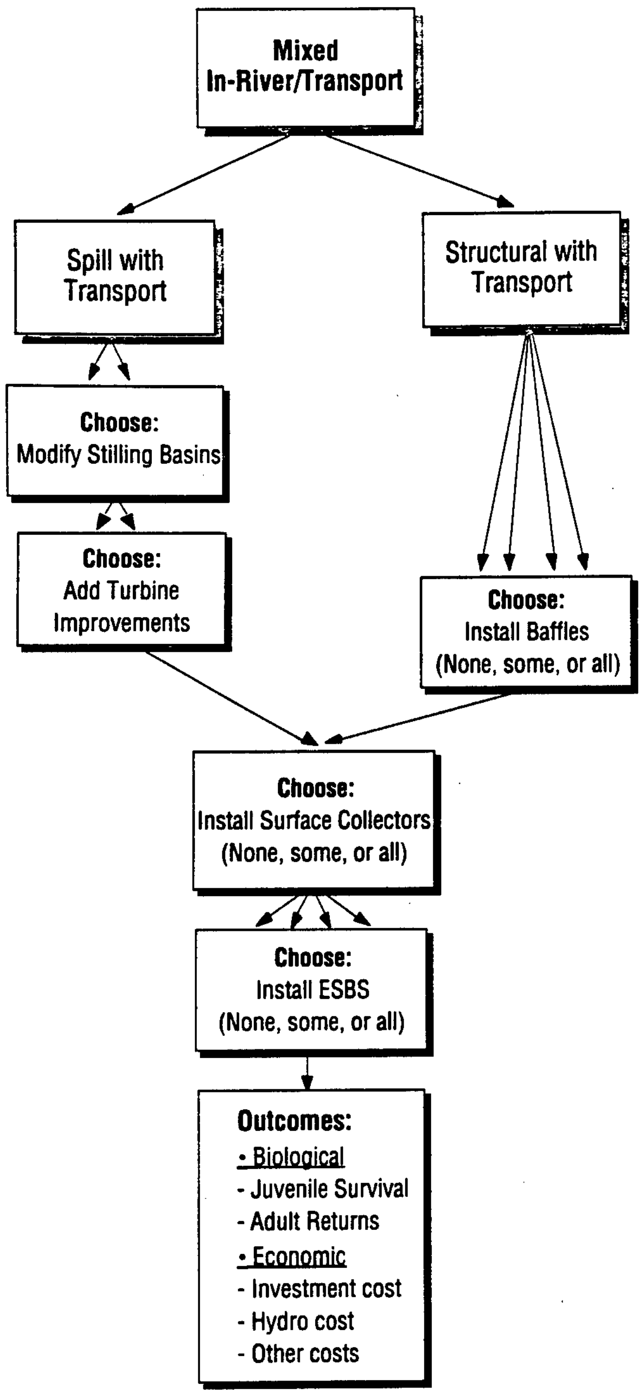
The branch involving spill includes consideration for various additional hardware improvements. These include surface bypass/collectors, extended length screens, stilling basin modifications, and turbine improvements. As demonstrated in the graphic subtree, any combination of the these structures can be considered, each with an anticipated level of improvement in juvenile survival. However, the survival enhancement would apply to a smaller proportion of juveniles than in the strict "in-river spill" option, because some percentage of juveniles would be transported.

The NMFS BiOp and SOR preferred alternative includes flow targets which affect the quantity of transported fish and level and timing of spill. Selection of this path would continue this approach, although some changes in flow targets could be included.

Structural Improvements with Transportation

The branch focused on non-spill, structural improvements in combination with transportation requires consideration for decisions on surface bypass/collectors and extended length screens. Unlike the "spill with transport" options, baffles could also be installed, which improves the efficiency of juveniles passing through spillways while reducing the 1995 BiOp large-scale spill program.

Figure 9-5: Mixed Path



The **Mixed (in-river/transportation)** options include:

1) use of spill with transportation, or
2) use of structural improvements with transportation

1) Spill may be used ...
   a) With our without stilling basin modifications; and
   b) With or without turbine improvements

2) Structural (non-spill) improvements may include ...
   a) Installing baffles at some or all sites

Both non-drawdown options include considering ...

Installation of surface bypass/collectors ...

and with or without the addition of extended-length submerged screens ...

Which results in a set of outcomes addressing biological, economic, or other criteria.

Based upon your objective, you can:
—Prune unacceptable paths
—Retain paths that might satisfy your objective, based on new data, or
—Select a single path as superior.

Section 10

RISKS AND UNCERTAINTIES FOR SALMON

Section 10 RISKS AND UNCERTAINTIES FOR SALMON

Risk and Uncertainty in Decision Analysis

The region is faced with the tremendous challenge, set forth by provisions of the Endangered Species Act, of restoring to sustaining levels the population of Snake River spring, summer, and fall chinook, as well as sockeye salmon. As noted elsewhere in this document (Section 3), restoration may require changes or improvements in many entities affecting the life cycle of the salmon. Some are potentially within the control of human intervention (e.g., harvest levels), but others are not (e.g., ocean conditions). Some can be implemented in a relatively short period of time (e.g., hydropower operations), while others will require considerable time (e.g., habitat improvement).

The scope of this study, and the charge of the Corps of Engineers, is focused on the operation of the Lower Snake River projects. The dam system structure and operation represents an important, but limited, element in the restoration of the species. Changes in the system can take place rather quickly, and with results that vary in degrees of predictability. However, these changes alone, independent of the "other Hs," cannot assure survival of the species because of inherent risk and uncertainty.

The question as to how best operate or change the Lower Snake River system is a microcosm of the larger salmon restoration issue. The three main paths (*Transportation*, *In-River*, or *Mixed*) represent different options for affecting juvenile and adult migration survival. Disagreement among interested parties in approach to salmon restoration is characterized in part by philosophical differences, but also by an inability to predict outcomes with certainty and the attitudes of respective parties towards risk and uncertainty.

This section is concerned with risk and uncertainty associated with salmon restoration, the influence of risk and uncertainty on the decision process, and the implications for management of the hydro system.

Definitions of Risk and Uncertainty

Risk and uncertainty are inherent in the natural world. Human intervention in natural processes involves unpredictable biological and economic elements. The objective of decision analysis is to incorporate the characteristics of risk and uncertainty into the decision process.

Risk is defined as a condition in which the potential outcomes, not equally desirable, can be described with reasonably well-known probability distributions. Examples include precipitation levels or floods. Although the range and distribution of potential outcomes is known from past events, actual (future) occurrences among outcomes cannot be predicted with certainty.

Uncertainty is a condition in which potential outcomes are not known and cannot be characterized by probability distributions. Uncertainty may result from imperfect information or a lack of definitive data, which conceivably could be obtained, or from circumstances which may not be defined probabilistically. Examples of uncertainty include future developments in alternative energy technology or long-term changes in regional population.

Salmon Recovery and Risk

Migrating juvenile salmon are subjected to the tremendous challenge of surviving the dams of the Lower Snake and Columbia Rivers. Until recently, the dams were operated in a manner targeted at balancing the requirements of the multiple uses of the system: hydropower generation, flood control, irrigation, recreation, navigation, and fish migration. Juvenile salmon needs for many decades were a low priority in this ranking, and fishery needs were often incompatible with overall system operations (Mighetto et al., 1994). Migrating salmon suffered high mortality through the system as a consequence.

The NMFS BiOp 1995 has resulted in managing the hydro system with fish requirements as the first priority. Subsequent actions in transportation methods, investment in structural improvements, dam removal, changes in river operations, or a combination strategy, are intended to further reduce risks associated with salmon recovery. Whereas before juvenile salmon mortality was a consequence of system management, the focus now is on mortality reduction.

There are other risks to be considered in the salmon recovery effort. Risk related to imple-

mentation time implies that even if a path will lead to a highly certain and improved environment for fish, migrating salmon will have to be exposed to existing, possibly less desirable, conditions during the interim and or construction. Thus, there may not be adequate time for the recovery action to work before extinction. There is also risk associated with budgetary constraints in the salmon recovery effort. At a certain level of expenditure, limits on available funds and manpower (regionally and nationally) for salmon recovery may require choices among investments in structural improvements, testing, experimentation, and monitoring efforts.

Uncertainty with respect to outcomes of actions also creates risk. Some measures or paths have unknown outcomes because there are no prototypes from which to draw implications (e.g., dam removal). Other measures may have uncertain results; prototypes may exist elsewhere but the results have limited or questionable transferability.

One way that planners can respond to uncertainty is to seek to reduce the uncertainty by acquiring more information. Uncertainty associated with some actions may be reduced by experimentation or testing. This is one of the reasons that NMFS has put off a decision regarding the hydro system until 1999. The resulting information from the NMFS study program may help to narrow the range of possible outcomes.

Sources of Risk and Uncertainty in Recovery Measures

Although changes in the hydro system may improve the likelihood of juvenile survival, risk and uncertainty are still evident among the recovery measures and paths. Table 10-1 outlines the general categories of risk and uncertainty affecting salmon recovery measures.

Table 10-1: Sources of Risk and Uncertainty

Sources	Examples
Variability in the natural world	Precipitation, annual stream flows; population fluctuations
Random interaction of independent human activities and natural processes	Regional economic conditions, future population growth, habitat loss
Measurement error, inconclusive results, or lack of definitive data	Untested or non-existent prototypes
Events may not be defined probabilistically	Future in energy technologies, future ocean conditions

Transportation of juveniles has been used for many years, and there is much empirical data to support expectations of a relatively high survival rate. The method also reduces significantly the influence of discharge on fish migration: transportation can take place in years of both high and low water. There is less certainty regarding the impact, if any, of transportation on the homing capabilities of adults returning to the Columbia and Snake Rivers. Some evidence has suggested a difference in homing capabilities between transported and "in-river" fish.

In-river methods have uncertain expected outcomes and some, such as dam removal, are more uncertain than others. The data are limited and factors affecting survival have not all been isolated. Current experiments, particularly with spill and comparisons with transportation coordinated with the 1995 NMFS BiOp, are anticipated to provide more definitive data. Although opportunity for using spill is highly dependent upon water availability, flow augmentation will reduce discharge variability.

Drawdown options vary in implementation time. Permanent natural river drawdowns, both two and four pool, will require structure removal which can be accomplished in approximately five years. The seasonal drawdown to spillway crest for one pool will also take five years, but a four pool could take ten years. Finally, a seasonal natural river drawdown would require extensive structural changes and would take at least fifteen years to implement. These time periods will play a role in the risk analysis, because in the interim juvenile salmon are subjected to existing conditions.

Technological or structural changes vary in terms of the certainty of impact on juvenile survival. For example, extended length submersible screens are in place at Lower Granite and effectiveness in guiding fish is well estimated. A high degree of confidence is placed on the applicability of this technology to other projects, and the FPE is reasonably well forecasted. In contrast, there is limited data on prototype surface bypass/collectors in place from which to gauge effectiveness. Sluiceways at other projects provide some supporting information, but the lack of empirical data result in a wider confidence interval on surface bypass/collector FPE estimates.

Role of Risk in Decision Making

Incorporating Risk

Individuals tend to have an aversion to the taking of risks, particularly when high values are at stake. Few people would be willing to wager a year's salary for a "fair" bet, because of

the potential for loss. Homeowners are willing to pay an annual premium for fire insurance despite the very small odds of a fire destroying one's house.

A similar attitude is evident among those concerned about salmon recovery. The relative merits of two hypothetical paths, one with high assurance of a particular outcome and another with a somewhat more favorable outcome but less certainty, is not as absolutely clear. The *risk* of a poor outcome associated with the latter may be too great for some people.

Attitudes towards risk will influence how paths are evaluated. For those individuals who are indifferent to risk or "risk neutral," an approach weighing expected or "most-likely" outcomes for each path will be adequate. In essence, uncertainty and variance in outcome does not influence choice among paths. For those who are risk averse, the chance that outcomes will deviate from the "most likely" outcome weigh against the particular path branch. Many are also concerned with minimizing the probability of "catastrophic losses"; that is, path branches with some (even small) probability of failure are eliminated despite their overall expected outcome. This latter approach is known as "safety first."

Accounting for Uncertainty

When decision makers face uncertainty about the magnitude of biological or economic benefits of alternative courses of action, decision rules and procedures should be modified to account for this uncertainty. One possible modification entails changing the sequence of choices so as to take advantage of additional information that might become available in the future from testing or data collection. In general it is beneficial to delay a decision when there is uncertainty about at least one of the choices. However, the delay should not be of such a duration as to put the resource (i.e., the salmon stock) in jeopardy of catastrophic loss that could otherwise be avoided. In other words, inaction is not beneficial unless additional information will materially improve the decision. Thus, to collect three more years of data but not use it in the Decision 1999 makes no sense if saving salmon is the goal.

The presence of uncertainty in outcome suggests that a sensitivity analysis should be conducted. The sensitivity analysis will weigh possible outcomes to determine if additional information (to be obtained through experimentation or testing) would influence the ranking or selection of paths. Such an analysis can play an important role in decisions made by the Corps of Engineers over the next three years.

Implications for Management of the Hydro System

Defining Decision Rules

There is disagreement in the region as to whether the primary objective of the salmon recovery effort is to increase juvenile survival or increase the smolt-to-adult-return rate. Similarly, there is not a consensus of attitude toward risk or the rules governing comparisons among alternatives. As a consequence, it is necessary to evaluate the decision tree from a variety of perspectives. This approach to evaluation will be presented in this section. Fortunately, the same structure may be used for the different perspectives.

The general procedure for comparisons among alternatives (sub-branches) is the following:

1. **Assess the biological effectiveness.** In this section, *biological effectiveness* is measured in terms of juvenile survival, considering estimates of mortality from various sources. Ranges in values reflect differences in underlying assumptions (such as FPE) and parameters (such as presumed mortality rates through turbines). Where a sub-path is clearly dominated biologically by another of equivalent cost, it may be eliminated from further consideration. Where a sub-path is indeterminate with another (i.e., their ranges overlap), there is indication that the path should not be eliminated on biological grounds alone.

2. **Consider the relative certainty of the information base.** Is there a strong empirical base for the biological estimates of outcomes? Is better information obtainable with testing or experimentation?

3. **Analyze the cost effectiveness.** Each action has impacts on system operation and other uses (power generation, recreation, navigation, etc.) and may involve an annualized investment cost. Estimates of impacts to other uses are measured in average annual dollars of direct and indirect cost. The costs associated with each alternative are plotted against the biological outcome. Those alternatives which achieve a similar *biological* benefit but at a higher total cost may be pruned from further consideration. Relative uncertainty of the biological outcome may enter into the decision.

4. **Identification of trade-offs associated with sub-paths.** Remaining sub-paths can be analyzed according to the associated trade-offs between, for example, hydropower production (widely dispersed impacts) versus irrigation supply (concentrated impacts). Other criteria, such as potential social acceptability, can be addressed.

5. **Other considerations.** For example, based upon different attitudes towards risk, decision makers could come to different conclusions on the relative merits of some paths.

6. **Prune additional sub-branches (if any) which do not meet other criteria.** For example, those alternatives which do not have regional acceptance or are highly controversial may be eliminated from further consideration. Some may also apply additional criteria, for example, a requirement that "fish remain in the river."

7. **Implications for research or testing over the next three years.** In those cases where selection among sub-paths is not definitive *and* where further research could be enlightening in the particular case, these can be noted.

Although this approach is generally applicable, differences in perspectives (and thus decision rules) affect how the data are analyzed. For the risk-neutral approach, it is sufficient to use a single "most likely" or "expected value" estimate for biological survival. Relative uncertainty may result in placing bounds on the expected values until additional information (through experimentation) may be obtained. The cost effectiveness analysis and subsequent pruning is thus quite simple at this point.

The range of high and low juvenile survival estimates are used in the risk-averse approach. Uncertainty can increase the size of these bounds, depending upon the source of the information gap. For example, lack of a prototype surface collector yields a fairly wide range of possible FGE estimates and, subsequently, a wide range in possible biological outcomes.

The cost effectiveness analysis and pruning are more restricted in the risk-averse approach because the biological outcomes may not be as determinate. It thus becomes necessary to conduct a sensitivity analysis to effectively determine the bounds on the outcomes; only those branches which are wholly dominated by others may be pruned.

The "safety-first" approach is similar to the risk-averse approach. However, branches may be pruned more readily if the bounds of possible outcomes contains an "unacceptably" low survival rate with relatively high certainty. For those alternatives, the risk of catastrophic loss is too great. However, if there is low certainty or a lack of information that may be remedied by further testing or analysis, the branch need not be pruned immediately.

A Sample Decision Analysis: Transportation Sub-path

Much of the necessary empirical information is lacking to evaluate the biological effectiveness of various combinations of improvements to the hydro system. As such, a complete decision analysis on any subtree is not possible. However, the lack of full information does not preclude making initial assessments of cost effectiveness, elimination of ineffective branches, and identifying areas of fruitful research. For purposes of demonstration, a sample decision analysis is applied to the Snake River System Transportation Sub-path.

Construction of the Sub-path Tree

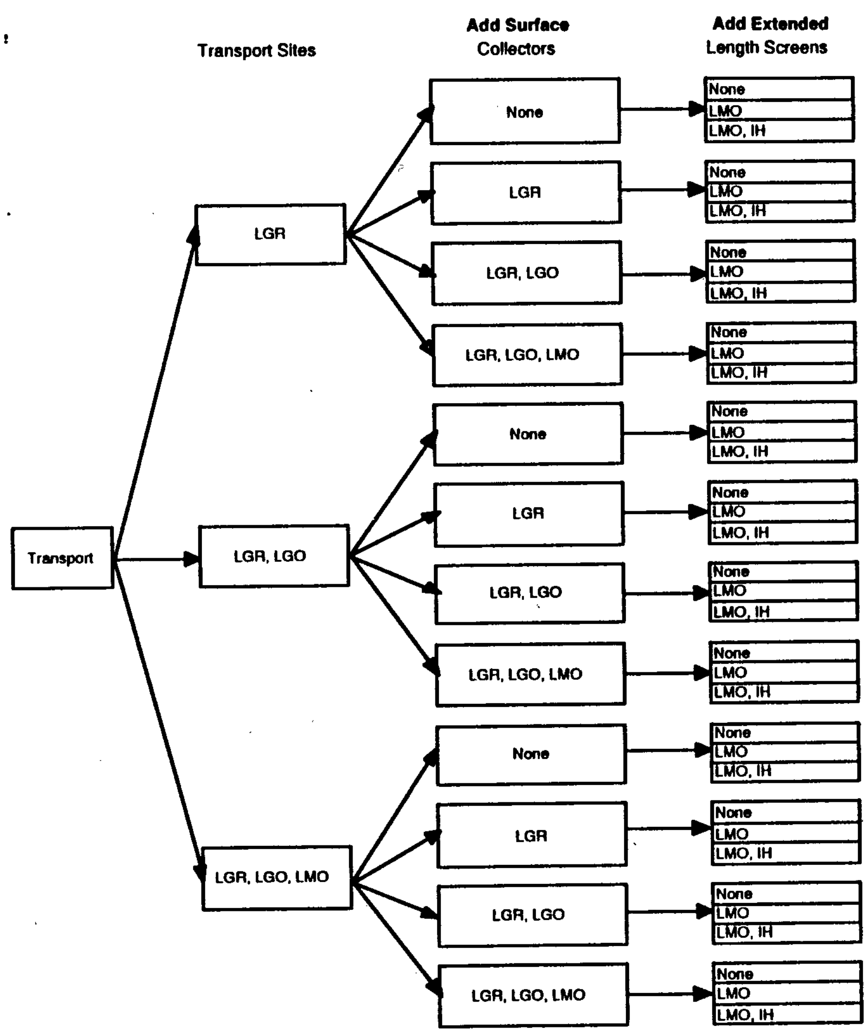
As described in the previous chapter, the *Transportation Sub-path* requires analysis of three general sets of decisions. First, will transportation of juveniles be conducted from one, two, or three sites (Lower Granite, Little Goose, and Lower Monumental)? Second, how many dams should have surface bypass/collectors installed? Third, should extended length submerged screens be added to Lower Monumental and Ice Harbor? The decision pattern is displayed graphically in Figure 10-1. The decision paths are demonstrated by following the arrows from left to right in the decision tree, through decisions of transport sites, surface collectors, and extended length screens.

Associated with each of the end "nodes" (of which there are 36 for the *Transportation Sub-path*) are a set of "outcomes." The outcomes are the resultant biological effects and economic costs — the consequences — of making the associated decisions. In this case, biological outcome is represented by "Juvenile Survival" percentage, although other measures (such as SAR) can be included. Economic costs are estimated by category, relative to the baseline, the 1995 NMFS BiOp.

A spreadsheet model was constructed to estimate juvenile survival under all combinations of these decisions (Figure 10-2). Survival rate was estimated by changing parameters reflected by the "implementation" of the combination of measures. For example, the uppermost three end nodes represent transportation of juveniles from only Lower Granite, without surface collectors, and with, respectively, none, one, or two *additional* extended length screens (at Lower Monumental and Ice Harbor).

Figure 10-1: Transportation Sub-Path

Transportation Subpath



Outcomes:

Juvenile Survival (Low)	Juvenile Survival (High)	SAR	Degree of Uncertainty	Investment Cost	Hydro Cost	Other Costs	Total Costs	Time to Implement: Years
Biological				Economic				
78.0	78.1		Low	$0.0	($186.0)	($18.3)	($204.3)	0.0
78.2	78.2		Low	$1.8	($186.0)	($18.3)	($202.5)	3.4
78.2	78.3		Low	$3.6	($186.0)	($18.3)	($200.7)	3.4
83.1	83.2		Med	$1.9	($185.1)	($18.3)	($201.5)	5.8
83.2	83.2		Med	$3.7	($185.1)	($18.3)	($199.7)	5.8
83.2	83.3		Med	$5.5	($185.1)	($18.3)	($197.9)	5.8
83.2	83.3		High	$3.8	($184.2)	($18.3)	($198.7)	5.8
83.3	83.3		High	$5.6	($184.2)	($18.3)	($196.9)	5.8
83.3	83.4		High	$7.4	($184.2)	($18.3)	($195.1)	5.8
83.4	83.5		High	$5.7	($183.3)	($18.3)	($195.9)	5.8
83.4	83.5		High	$7.5	($183.3)	($18.3)	($194.1)	5.8
83.5	83.6		High	$9.3	($183.3)	($18.3)	($192.3)	5.8
85.5	85.5		Low	$0.0	($186.0)	($18.3)	($204.3)	0.0
85.5	85.6		Low	$1.8	($186.0)	($18.3)	($202.5)	3.4
85.6	85.7		Low	$3.6	($186.0)	($18.3)	($200.7)	3.4
88.0	88.1		Med	$1.9	($185.1)	($18.3)	($201.5)	5.8
88.1	88.2		Med	$3.7	($185.1)	($18.3)	($199.7)	5.8
88.1	88.2		Med	$5.5	($185.1)	($18.3)	($197.9)	5.8
88.8	88.8		High	$3.8	($184.2)	($18.3)	($198.7)	5.8
88.8	88.9		High	$5.6	($184.2)	($18.3)	($196.9)	5.8
88.9	89.0		High	$7.4	($184.2)	($18.3)	($195.1)	5.8
88.9	89.0		High	$5.7	($183.3)	($18.3)	($195.9)	5.8
88.9	89.0		High	$7.5	($183.3)	($18.3)	($194.1)	5.8
88.9	89.0		High	$9.3	($183.3)	($18.3)	($192.3)	5.8
86.9	87.0 1/		Low	$0.0	($186.0)	($18.3)	($204.3)	0.0
87.2	87.2		Low	$1.8	($186.0)	($18.3)	($202.5)	3.4
87.2	87.3		Low	$3.6	($186.0)	($18.3)	($200.7)	3.4
89.0	89.1		Med	$1.9	($185.1)	($18.3)	($201.5)	5.8
89.2	89.2		Med	$3.7	($185.1)	($18.3)	($199.7)	5.8
89.2	89.3		Med	$5.5	($185.1)	($18.3)	($197.9)	5.8
89.5	89.6		High	$3.8	($184.2)	($18.3)	($198.7)	5.8
89.6	89.7		High	$5.6	($184.2)	($18.3)	($196.9)	5.8
89.6	89.7		High	$7.4	($184.2)	($18.3)	($195.1)	5.8
89.7	89.8		High	$5.7	($183.3)	($18.3)	($195.9)	5.8
89.7	89.8		High	$7.5	($183.3)	($18.3)	($194.1)	5.8
89.7	89.8 2/		High	$9.3	($183.3)	($18.3)	($192.3)	5.8

1/ 2/ See Figure 10-3 for these two "Best" options

Figure 10-2: Snake River Project Juvenile Survival

Project Assumptions:	95%		98%			99%	90%	
	Reservoir Survival*	**Portion to Spillway**	**Spillway Survival**	**Portion to Turb Entr**	**Bypass FPE**	**JBS Survival**	**Turbine Survival**	**OVERALL SURVIVAL**
Lower Granite								
Assumptions:					**70%**			
100.0	95.00	0%	0.00	100%	66.50	65.84	25.65	25.65
100.0	95.00	0%	0.00	100%	66.50	65.84	25.65	25.65
					Transported			
Little Goose								
Assumptions:					**70%**			
25.65	24.37	0%	0.00	100%	17.06	16.89	6.58	6.58
25.65	24.37	0%	0.00	100%	17.06	16.89	6.58	6.58
					Transported			
Lower Monumental								
Assumptions:					**60%**			
6.58	6.25	0%	0.00	100%	3.75	3.71	2.25	2.25
6.58	6.25	.0%	0.00	100%	3.75	3.71	2.25	2.25
					Transported			
Ice Harbor								
Assumptions:					**70%**			
2.25	2.14	10%	0.21	90%	1.35	1.33	0.52	2.06
.25	2.14	80%	1.68	20%	0.30	0.30	0.12	2.09
Lower Columbia								
2.06	90% Survival through each of 4 dams				**1.35**			
.09	90% Survival through each of 4 dams				**1.37**			
Transported Juveniles:		**LGR**	**LGO**	**LMO**	**All**	**99% Survival**		**OVERALL SURVIVAL**
99%		65.84	16.89	3.71	86.43	**85.57**		**86.92**
Survival		65.84	16.89	3.71	86.43	**85.57**		**86.94**

* Accounts for mortality from indirect causes: reservoir, predation, disease, etc.

Assessing Biological Effectiveness: Folding Back the Tree

Juvenile survival estimates in the *Transportation Sub-path* display a distinct and logical pattern: the more structural improvements, the higher the survival guidance rate. Guidance is a surrogate for survival because we do not have actual long-term survival or adult return data for each transportation option. On a strictly biological basis (with juvenile guidance as the only criteria), the evaluation of the tree would proceed as follows:

- Comparisons of juvenile survival rates are made *right to left* from the tips. Where two or more branches emanate from a decision node, outcomes are thus compared, and all but the highest valued branches are eliminated ("pruned").

- Comparisons continue right to left, through the "surface collectors" decisions and finally, to decisions on selection of transport sites. All sub-paths but those with the highest juvenile survival guidance rates are eliminated. Ultimately, the dominant path or paths are those which remain after all others are "pruned."

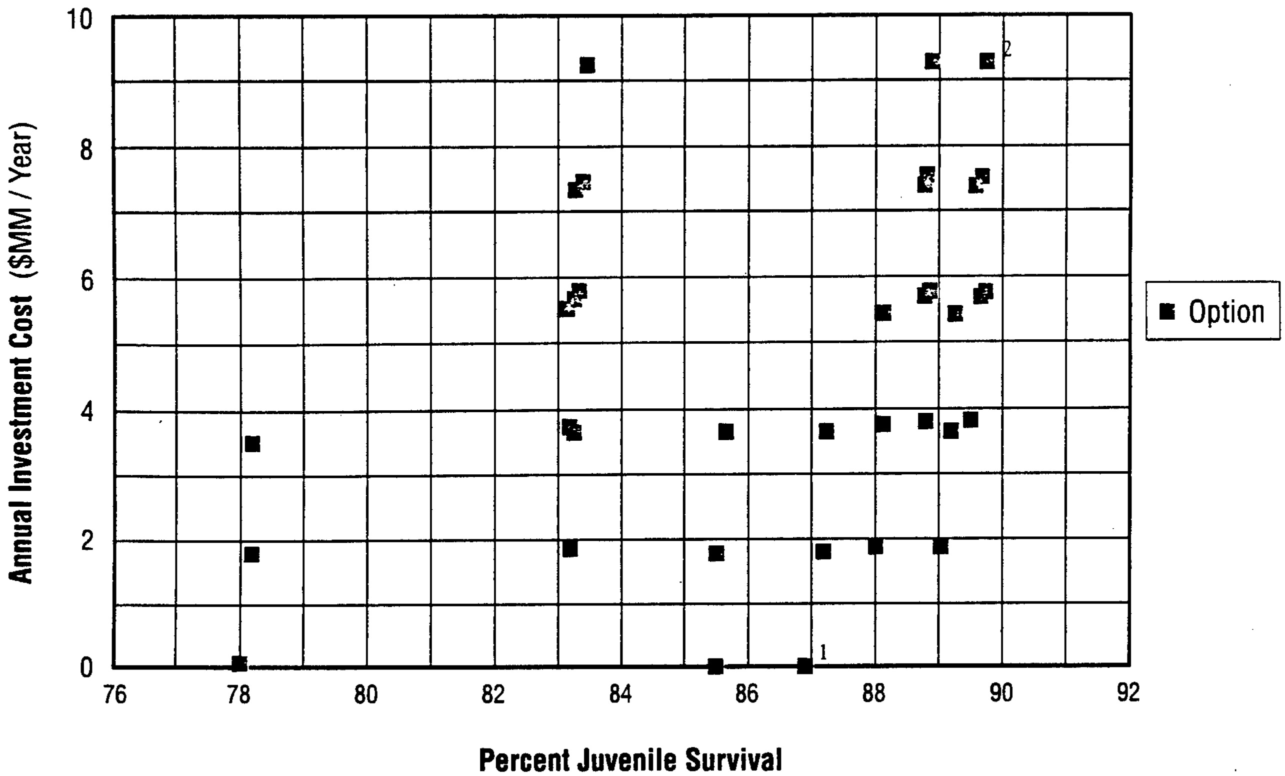
In this case, the biological solution to the decision analysis is trivial. It may be that for $10 million annually we can increase guidance from 87 to 90 percent, but with considerable risk. But what if survival rates are not discrete but rather defined probabilistically? Or what if long-term survival (SAR) is affected by the type of screen facility? In such a case the analysis requires that outcomes (e.g., juvenile or adult return rate survival) be computed as an expected value with associated variance. The comparison of sub-paths is dependent upon the decision rules and, because of overlap or inadequate data, becomes less clear.

Merging Biological Outcome with Cost Effectiveness

Using a single-outcome measure of effectiveness such as juvenile survival has merit in determining the best possible outcome. However, the region is also concerned with economic and other trade-offs associated with recovery options. It becomes important to recognize, for example, the full cost of attaining each increment of improvement in a biological outcome. This will help to determine the socially optimal level of recovery investment: weighing the benefits of salmon recovery with its overall cost. Even if the region cannot agree on the optimal recovery level, it is still important to determine the least cost means of achieving each level of biological benefit.

Cost effectiveness analysis is a technique used to analyze biological and economic infor-

Figure 10-3: Cost Effectiveness of Transportation Sub-Path



[1] Cost Benefit "Best" (see Figure 10-1)
[2] Biologically "Best" (see Figure 10-1)

mation together. Figure 10-3 displays the results of this analysis as applied to the *Transportation Sub-path.* Biological outcomes (survival) on the vertical axis and annual investment cost[2] on the horizontal axis provide 36 data points (one for each path) for comparison (Figure 10-1). A line drawn from left to right through the lowest points indicates the *least cost frontier*, and thus, the least expensive means for attaining a given level of biological outcome. In this example, survival rates of 78 percent through 86.9 percent can be attained without additional investment above the 1995 NMFS BiOp; these are the paths represented by transportation with no additional structures. However, the next increment of biological benefit (to 87.2 percent) will require an incremental cost of $1.8 million annually, indicated by the addition of a screen at Lower Monumental and transport from three sites. The least cost frontier continues to the right: a survival rate of 89 percent

[2] In general, total cost is presented rather than just the investment cost. However, annual investment is shown here for clarity of presentation.

for an annual cost of $1.9 million (surface collector at Lower Granite) on up to a maximum rate of 89.7 percent for $5.7 million (surface collector at three sites).

Two important aspects are associated with the least cost frontier:

1. All points, representing biological outcomes and associated costs, above the frontier are inferior to those directly *on* the frontier, because a similar biological outcome is possible at a lower cost.

2. The vertical difference between two horizontal points on the frontier represents the incremental economic cost of attaining the increment of biological gain. Therefore, in this example, the cost of increasing survival from 86.9 percent to 87.2 percent is $1.8 million annually. However, the cost of increasing survival from 89 percent to 89.7 percent is $3.8 million annually ($5.7 million minus $1.9 million).

Thus, the least cost means of attaining a biological outcome can be determined, and the marginal cost to society of achieving a particular increment of biological benefit can be estimated.

Summary and Conclusions About Decision Analysis

Decision analysis is a useful tool for graphically displaying and analytically evaluating the complexity of problems involving a range of options and interaction of multiple potential decisions. It also provides the most reasonable means for incorporating risk and uncertainty in the decision-making process, the framework for evaluation under alternative attitudes towards risk, and a structure with which the region can systematically weigh alternative actions.

Decisions regarding salmon recovery measures are not only complex but involve considerable risk and uncertainty. Many aspects of probabilistic risk affecting salmon, particularly ocean conditions and habitat, are not within the realm of hydro system operation and cannot be easily considered. Some elements, such as available annual flow, can be defined probabilistically but also managed within the hydro system in a manner that is optimal for salmon. But there are also many structural improvements, such as surface collectors, or system changes, such as embankment removal, which have uncertain outcomes, primarily from a lack of prototype and sufficient data.

With the decision analysis structure in place, it becomes possible to recognize and consider those decision elements which: 1) are not biologically sound or not cost effective; 2)

may have some merit but adequate data is lacking; and 3) are reasonable and prudent, given the information available. At present, much of the biological information in the structure is insufficient to allow "pruning" of the decision tree. This is because much uncertainty exists regarding overall juvenile survival and adult return rates for transport versus in-river migrants. Additional data on new tools will be collected over the next three years. These may help prune major branches. However, the complexity of options combined with the variability of biological data suggest Decision Analysis is not likely to provide a clear simple answer as to which path to choose. Decision Analysis does, however, provide useful framework for evaluating biological, economic, and uncertainty tradefoffs associated with alternative recovery sub-paths.

Section 11

FUTURE STUDIES, DATA, AND ANALYSES

Section 11 FUTURE STUDIES, DATA, AND ANALYSES

In Section 7 we discussed the path selection process and the criteria that will be used to select a final hydro system operation in 1999. In this chapter we describe the studies, data, and the analyses needed to establish specific values for each criteria. We use the preliminary results of the 1994 Spring/Summer chinook PIT-tag data to demonstrate key points regarding treatment groups, experimental handling and statistical analysis on the interpretation of study results.

We begin with a brief overview of the primary fish marking technology that will be used for collecting the population data needed for path selection.

PIT-Tag Technology

Passive Integrated Transponder tags (PIT tags) are small electronic devices that are inserted into the fishes body cavity and thus allow researchers to monitor individual fish through the juvenile and adult stages of their life cycle. We can track juvenile fish as they migrate through the hydroelectric system and identify their specific passage route. For example, we can tell whether or not a PIT-tagged juvenile encountered a bypass facility, entered a barge for transportation, or was returned to the river to continue its downstream migration. PIT-tag detectors located at key locations at six different hydroelectric facilities on the Columbia and Snake rivers provide this information. Other information that can be obtained from the use of PIT-tagged fish include juvenile travel-time and survival from project to project, and adult return rate by species and migration path (e.g., transport versus in-river).

It will be the results of PIT-tag experiments conducted from 1994 through 1999 which will be used to select the preferred hydro system operation (path). A brief description of these experiments are described below.

PIT-Tag Studies

The three major PIT-tag studies currently in progress in the Snake and Columbia rivers are as follows:

- ***The NMFS/UW Juvenile Reach Survival Study.*** This study is designed to quantify juvenile survival through the hydroelectric system. Juvenile survival estimates are calculated by reach (project to project), migration route (turbines, spill, bypass facilities) and species (chinook, steelhead). The data from this experiment are incorporated into the CRiSP model which is then used to predict an overall system survival for Snake River stocks, predict the TIR values for experimental groups and to play "what if" scenarios regarding system operations.

- ***The NMFS Juvenile Transportation Study.*** In 1995 staff from the NMFS began year one of a three year program to determine the effectiveness of the current barge transportation program. In 1995, approximately 230,000 spring chinook juveniles were captured over the course of the migration season at Lower Granite Dam and marked using a combination of PIT tags, CWTs, and Freeze Brands. Of the 230,000 fish marked, 100,000 were loaded onto barges and transported to below Bonneville Dam. The other 130,000 were released into the Lower Granite tailrace and were allowed to migrate in-river through the hydroelectric system. The sample sizes of the two groups were established so that a 30 percent difference in adult returns between the two groups could be detected as long as the adults return at a rate of about 0.2 percent or more. This experiment will be repeated with smaller sample sizes in 1996 and 1997. In future years, the NMFS will compare the number of adults returning to Lower Granite Dam from each group. They will use this comparison to establish the smolt-to-adult return rates (SARs) for each group as well as the TIR between groups.

- ***Idaho Mainstem Passage Experiment.*** In this experiment staff from the Idaho Department of Fish and Game marked approximately 110,000 juvenile spring/summer chinook prior to their release from upstream hatcheries. These fish will act as a control group to determine the effects fish handling has on study results for the NMFS transportation study. The NMFS control group is made up of hatchery fish tagged and released from Lower Granite dam (i.e., handled fish). The resulting adult returns from the two groups will be compared to quantify the effects handling has on the results of the two experiments.

It is the adult returns from these studies that will be used to answer specific research questions regarding the selection of a preferred hydro system operation in 1999. These research questions include:

- Which path produces the highest SARs? The path with the highest SAR is deemed the preferred path.
- What is the difference in SARs between paths? Establishes the TIR between paths. The TIR is used in the path selection process as one of the two primary criteria for selecting or rejecting the full *Transportation* and *Mixed Paths*.
- Do transported juveniles produce more returning adults than juveniles allowed to migrate in-river? Selects or eliminates the full *Transportation Path* from further consideration.
- Are adult return rates influenced by the number of times a juvenile is detected at a collection facility? If true, *In-River* options that emphasize juvenile passage over spillways, sluices, etc., would be preferable than passage through screening systems.
- Do flow, water temperature, and/or juvenile travel-time influence juvenile survival and subsequent adult return rates? Addresses the need for selecting a *Mixed Path* due to river condition, need for flow augmentation, and dam removal.
- Do PIT-tag fish that were released upstream of Lower Granite Dam return in higher numbers than the NMFS Transportation study fish? Answers the question of whether the tagging of juveniles at the projects influences study results by decreasing SARs. This in turn influences path selection.

Preliminary 1994 PIT-Tag Database Analysis

We completed an exploratory analysis of the 1994 Spring/Summer chinook PIT-tag data to demonstrate how the results of the three major PIT-tag studies described above can be used for selecting a path in 1999. We also use these data to illustrate key points regarding how the selection of experimental treatment groups, and effects of bypass systems and handling may influence the interpretation of study results. We cannot emphasize enough the fact that these data are preliminary and not the final data set. These data are used simply as a tool to demonstrate future data analyses. Conclusions drawn from these data are at best speculative at this point in time. Staff from the NMFS are aware of these data and will be completing a full analysis of the data when adult returns are complete in 1997. The inclusion of the 1997 adult returns will substantially increase the preliminary SARs, especially for wild fish. Thus, these SARs should not be viewed as either precise SAR estimates or final path comparisons.

The Methods

We began by examining the release location, origin, migration route, and detection history of every returning adult (n=39) from the 1994 spring/summer chinook juvenile migration. From this examination we were able to identify eight possible experimental groups which could be used for selecting a preferred hydro system operation in 1999. The groups are:

- **Wild Transport.** These are wild juvenile chinook which were PIT-tagged upstream of Lower Granite dam, diverted by screens into a juvenile PIT-tag facility, and transported by barge/truck to below Bonneville Dam.
- **Hatchery Transport.** These are hatchery juvenile chinook which were PIT-tagged upstream of Lower Granite dam, diverted by screens into a juvenile PIT-tag facility, and transported by barge/truck to below Bonneville Dam.
- **Project Released Transport.** Hatchery juveniles PIT-tagged either at Lower Granite, Little Goose, or Lower Monumental Dam, and transported by barge/truck to below Bonneville Dam.
- **Project Released In-river.** Same as for Project Released Transport with the exception that these juvenile migrated through the hydro system in-river.
- **Not-Detected Hatchery.** This group of PIT-tagged fish were never detected at any of the PIT-tag detector facilities during the juvenile migration portion of their life cycle. It is assumed that these fish migrated as juveniles past each project either through spillways or turbines. In other words, these fish were in-river migrants that never encountered a juvenile bypass system.
- **Not-Detected Wild.** Same as for Not-Detected Hatchery.
- **Detected Hatchery.** According to their PIT-tag record these fish were detected at one to four different hydroelectric projects and continued their migration in-river.
- **Detected Wild.** Same as for Detected Hatchery.

After establishing the eight treatment groups we then calculated a juvenile sample size[1]

[1] Juvenile sample sizes for each PIT-tag group were developed by the National Marine Fisheries Service.

and the smolt-to-adult return rate (SAR) for each of the groups.[2] The results of the SAR calculation by group are presented in Figure 11-1.

The Results

Selection of Test Groups

The data in Figure 11-1 clearly illustrate that resulting SARs can vary dramatically depending on migration route, tagging location, and whether you are dealing with hatchery or wild fish. The range of SARs vary from a high of 0.15 percent for the Wild Transport group to a low of 0.002 percent for hatchery fish released at the projects and migrating in-river. In other words, the Wild Transport group had an adult return rate which was 75 times as large as the hatchery group released from the projects. The juvenile sample size for all groups (combined) was 134,000.

From the 1994 SAR data it is evident the selection of the treatment groups used in determining whether path criteria are met is critical as SARs may be highly variable. This is why throughout the path selection process described in Section 7 we emphasized using only the SARs from wild fish for path selection.

Path Comparisons

Once the SAR has been established for each path comparisons can then be made to determine which path produces the most returning adults. In Figure 11-2 we show both the SAR and the resulting TIR for transported versus in-river migrants in 1994. These data indicate that transported fish produced 2.9 times as many adults as juveniles allowed to migrate in-river. A statistical analysis of the SAR data using Chi-Square showed that despite a sample size of only 31 adults the difference was significant at the 0.01 level.[3] It should be noted that this comparison included both hatchery and wild fish. When these two groups are examined separately the results change dramatically as shown graphically in Figure 11-3. Again, this indicates that hatchery and wild may not respond the same to different paths.

[2] The juvenile sample sizes for the not-detected groups were based the results of SURPH model runs completed by staff from the University of Washington.

[3] In all figures where a statistical comparison is made the analysis method used was Chi-Square.

Figure 11-1: Percent Adult Return Rate by Detection History/Migration Route for PIT-Tagged Snake River Spring/Summer Chinook Juveniles (1994)

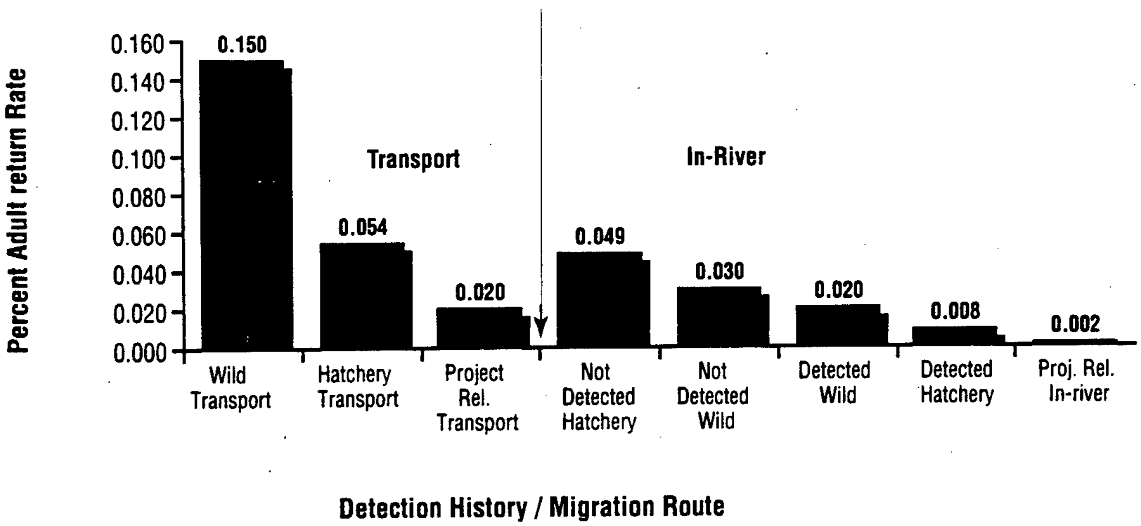


Figure 11-2: Percent Adult Return Rate for Transported vs. In-River PIT-Tagged Spring/Summer Chinook Juveniles (1994)

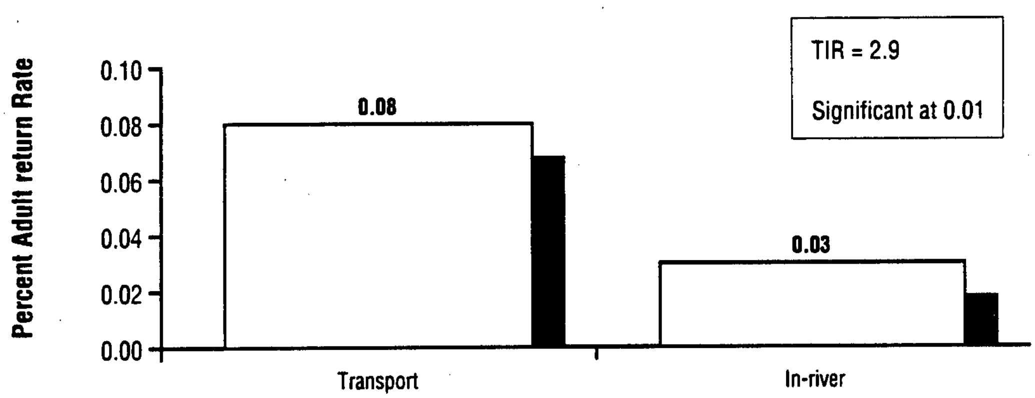
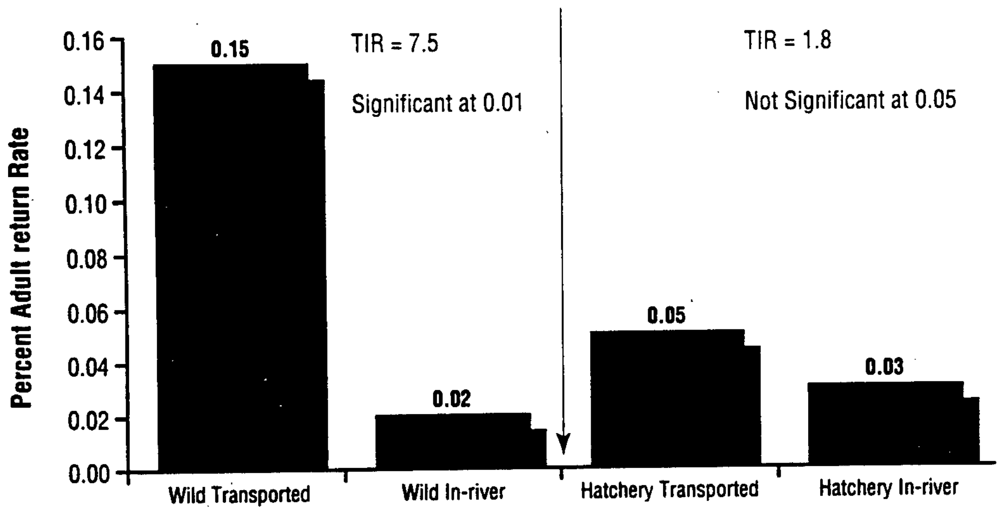


Figure 11-3: Percent Adult Return Rates by Migration Route for PIT-Tagged Wild and Hatchery Spring/Summer Chinook (1994)



The data presented in Figure 11-3 show that transported wild fish produced 7.5 times as many adults as wild in-river migrants. Transported hatchery fish on the other hand produced only 1.8 times as many adults as their in-river counterparts. It is these types of comparisons which will be used to determine which path, *Transportation*, *In-River*, or *Mixed* returns the most adults in any given migration year.

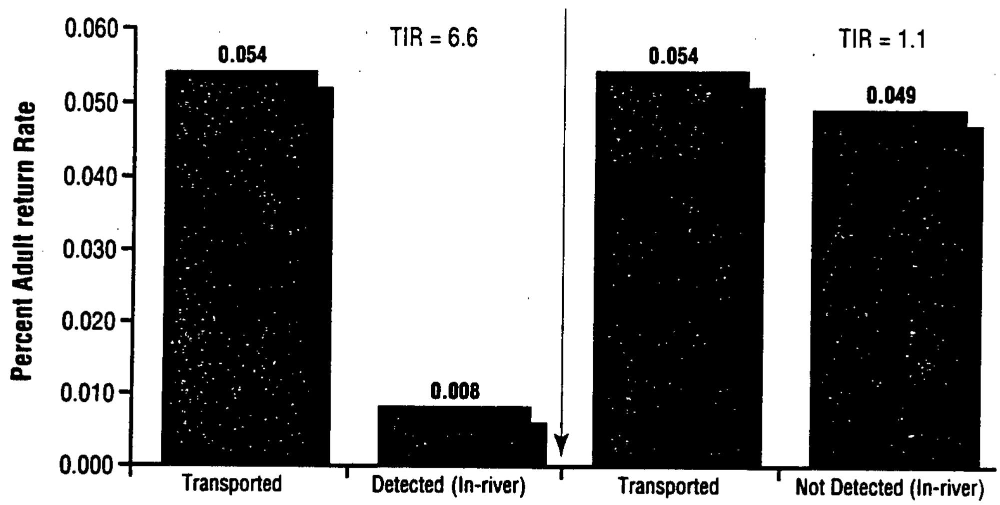
Effects of Juvenile Bypass Systems on SARs

In our review of proposed Snake River reservoir drawdown alternatives we analyzed both juvenile and adult PIT-tag data to determine trends in adult return rates based on juvenile detection history (Harza, 1994). The results of this analysis showed that a group of juvenile migrants in 1989 that did not encounter a juvenile bypass facility (Not-detected) returned many more adults than those that did encounter such facilities. The data suggested that juvenile exposure to existing bypass systems may be reducing SAR more than expected by random chance. A similar pattern is seen in the 1994 data (Figures 11-1 and 11-4).

For those juveniles which migrated in-river in 1994 the two groups with the highest adult return rate were the Not-detected hatchery and Not-detected wild fish (Figure 11-1). The

SARs for the two groups were almost twice as large as any other in-river group. And in fact, the Not-detected Hatchery group has an SAR about equal to the Hatchery Transport group (Figure 11-4).

Figure 11-4: Percent Adult Return Rate for Transported vs. Detected and Transported vs. Not Detected Hatchery Spring/Summer Chinook (1994)



The importance of these data is two-fold:

First, it alerts us to a group of in-river fish that may have the capability of producing as many or more returning adults than any other path. If we fail to examine this group in more detail we risk choosing an inferior path as our preferred alternative.

Second, if this same pattern is repeated with new adult return data on *wild* fish, it will have a profound influence on the tools we select for increasing juvenile survival via in-river migration. If juvenile exposure to collection facilities decreases SARs then we must select tools which emphasize juvenile passage through spillways (and sluiceways) to maximize the SAR for the *In-River Path.* We may even have to consider removing our existing fish passage facilities and either replacing them with new designs (e.g., surface collectors) or allow more migrants to pass the projects through turbines.

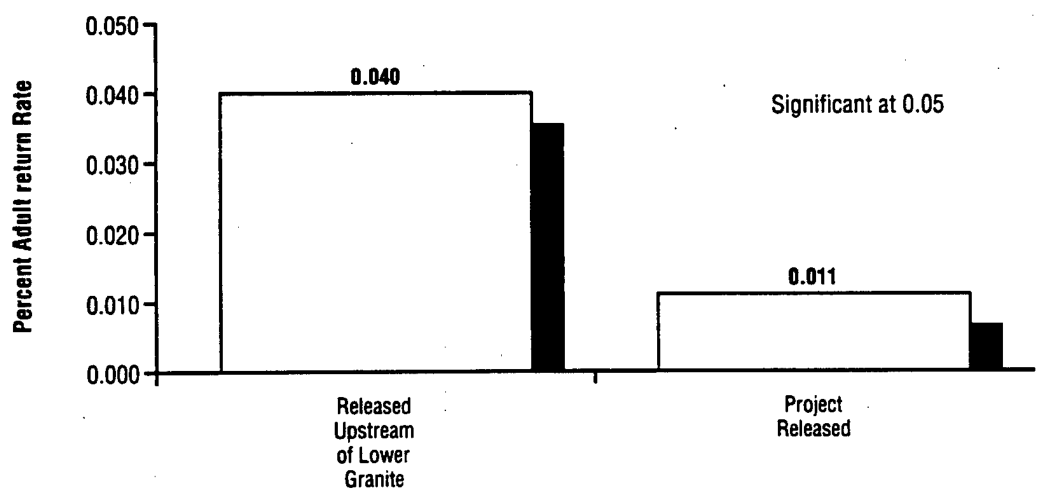
Effects of Handling on Experimental Results

Reviewers of past transportation studies have expressed a concern that the handling and marking of actively migrating juveniles (smolts) may diminish the SARs of these tagged fish. The 1994 PIT-tag data lend some support to this hypothesis.

The group with one of the lowest SAR to date are those hatchery fish that were tagged at the projects and released in-river (Figure 11-1). The SAR for this group currently stands at 0.002 percent. In comparison the SAR for the Not-Detected Hatchery group is 20 times larger at 0.04 percent. However, it should be noted that some of the hatchery fish released at the projects may have experienced a higher mortality level due to experimental design. For example, some of these fish were released directly into turbines to estimate direct turbine mortality.

Another indicator that the handling and tagging of juvenile migrants at the projects may be depressing SARs can be found by examining the data for hatchery fish tagged upstream of Lower Granite dam versus those released at the projects (Figure 11-5). Currently, the hatchery fish released upstream of Lower Granite dam have an SAR approximately four times larger than the project released fish.

Figure 11-5: Percent Adult Return Rate for Hatchery Spring/Summer Chinook Juveniles PIT-Tagged and Released Upstream of Lower Granite Dam vs. at the Lower Snake River Projects (1994)



While these data indicate that the marking and handling of juveniles at the projects may be decreasing SARs, it should be noted that these data pertain to hatchery and not wild fish. Additionally, these data were collected under the low flow conditions which existed in the Snake River in 1994. The effects handling has on study results may be completely different during years with higher flows.

The effects handling may have on wild juveniles will not be known until 1998 when the adult returns are complete for the 1995 juvenile migration. In 1995, the NMFS tagged approximately 40,000 wild spring/summer chinook at Lower Granite dam as part of their transportation evaluation.

If we find that handling or JBS exposure does affect SARs, we will need to adjust actual or potential SARs to some different level. Assuming that handling reduced SARs, then unhandled fish would be the benchmark to make this adjustment as to theoretical improvements of increased spill/FPE. The adjustment would also affect SAR and path decision criteria described in figures 1-2 and 1-3.

A New PIT-Tag Study: The Adult Passage Experiment

A major objection to past transportation data was that adult returns were measured to Lower Granite Dam and not the spawning grounds. Although the TIRs observed in river reaches above Lower Granite Dam were usually greater than 1.0, they were less than the 1.5 to 2.5 observed at Lower Granite Dam. Based on very small sample sizes these data suggest decreased survival of adults transported as juveniles once they pass Lower Granite Dam. The aggregate comparisons were not statiscally significant. A potential mechanism for such a phenomena, if it exists, would be impaired homing ability of transported fish.

To resolve this question, proposed studies must include statistically adequate sampling of the spawning grounds and upstream hatcheries for tagged fish. This will be accomplished with current NMFS transportation study plans as both transport and in-river adults detected at Lower Granite Dam will be captured, jaw-tagged, and released to continue their migration. These jaw-tags will be recovered by biologists working on the spawning grounds, hatcheries, and at adult traps located throughout the basin. This increase in sampling should result in an increase in sample size which will increase statistical rigor around estimates of TIRs to locations above Lower Granite Dam.

The evaluation of adult homing impairment would be greatly strengthened by using PIT tags as the evaluation tool and installing adult PIT-tag detectors at five key locations in the Columbia River basin:

- Bonneville
- Priest Rapids
- McNary
- Tributary Weirs
- Hatcheries

TIRs could then be compared at multiple locations over a longer stretch of river. Currently, we can only adequately measure adult PIT-tag returns to a single point, Lower Granite Dam.

The evaluation criteria for identifying homing problems in transported fish are straightforward. PIT-tagged adults are counted and tracked at each sample location. TIRs are calculated for each group by site. Decreasing trends in TIRs from downstream to upstream sampling sites is an indication of homing impairment.

Because adults from transport and in-river groups may not be detected equally at projects with more than one fish ladder, adult survival rates between detection sites will also be compared as a second method for determining adult homing impairment. This type of analysis would be performed in a similar manner as the jaw-tag evaluation conducted at Bonneville Dam in 1986, 1987, 1989 and 1990. In this study, transport and in-river adults were jaw-tagged at Bonneville Dam, and then re-released to the river. All jaw-tagged fish that arrived at Lower Granite dam were then diverted into a trap where the jaw-tag numbers were recorded.

During the four years the studies were conducted 27 transport and six control (in-river) adults were tagged at Bonneville dam. From these releases 10 transport and one control were captured at Lower Granite dam. Based on these numbers the survival rate of the transport and control groups to Lower Granite Dam were 37 and 16 percent, respectively.

The adult passage study should be repeated in 1997 to take advantage of the large number of PIT-tagged adult fish expected to return from the 1995 juvenile outmigration. At a minimum, an adult PIT-tag detector will need to be installed at Bonneville in order to collect this type of survival data.

Appendix A

1996 SURFACE COLLECTOR RESEARCH

Appendix A 1996 SURFACE COLLECTOR RESEARCH

Introduction

In 1996 various owners and operators of major hydroelectric projects in the region conducted tests of a relatively new fish bypass technology known as surface collection. Tests of this new technology were conducted in the spring of 1996 at Lower Granite (Snake River), Cowlitz Falls (Cowlitz River), and the following Columbia River hydroelectric projects: Bonneville First and Second Powerhouses, The Dalles, Wanapum, Rocky Reach, and Rock Island.

Because testing at these projects has either just been recently completed or is still in progress, preliminary study results were available for only Lower Granite and Cowlitz Falls. Study results from the other projects will not be readily available until fall of 1996.

In this section of the report we review the results of surface collection studies performed at Lower Granite and Cowlitz Falls dams. We begin with a discussion of the research conducted at Lower Granite Dam.

Lower Granite

In 1996 the Walla Walla District Corps of Engineers installed and tested a surface bypass and collector (SBC) at Lower Granite Dam. The SBC was installed over turbine units 4-6 and was tested from April 22 to June 1. The focus of the Lower Granite SBC program was to determine whether or not juvenile salmonids would enter and pass through such a system, and also determine the type of SBC entrance configuration that would maximize fish passage.

The technologies used to evaluate the SBC included radio telemetry (behavior), mobile and fixed hydroacoustic surveys (behavior and fish passage), ADCP (water velocities), and HI-Z balloon tags (survival).

The major conclusions of the 1996 study program are presented below along with a discussion as to the effect(s) they may have on future SBC research and the path selection process described in Section 7.

1. Both radio telemetry and hydroacoustic data indicated that about 40-50 percent of the fish approaching turbines 4-6 entered and passed through the SBC.

   The fish guidance efficiency (FGE) of the system was therefore approximately 45 percent. This FGE value is similar to the FGE obtained at Cowlitz Falls Dam for steelhead marked and released upstream of the project (see Cowlitz Falls). This level of FGE is insufficient to meet the NMFS mandated 80 percent FPE, or the 90 percent collection goal for the *Transportation Path* without assistance from other fish guidance structures.

2. The FGE of the extended submerged bar screens (ESBS) located in turbine 5 below the SBC and in turbine 2 adjacent to the SBC were approximately 80 percent and 60 percent, respectively.

   The difference in FGE between the two turbines could be a result of turbine operations, or from the effect the SBC has on fish behavior. If the increase in FGE observed at turbine 5 is due to the presence of the SBC, then overall FPE could be as high as 90 percent for a combination SBC and ESBS system. A 90 percent FPE would exceed the NMFS mandated 80 percent FPE target and satisfy the *Transportation Path* 90 percent collection efficiency goal. If the project FGE of the ESBS system is 60 percent, then only the NMFS 80 percent FPE goal can be achieved with the SBC/ESBS combination system. This type of system would satisfy most of the path goals for the *Mixed Strategy* or *In-River — No Transportation Path.*

3. Steelhead survival through the SBC was comparable to survival rates through spillways.

   The result makes sense since the SBC discharge was passed through a spillway gate. The result indicates that the SBC can be effectively substituted for a spill program which passes approximately 45 percent of the river.[1] The SBC also provides the benefit of reducing TDG levels downstream of the project in comparison to the 45 percent spill program.

[1] Assumes 1 percent spill passes 1 percent of the juvenile migrants.

4. Juvenile travel time past the project decreased in comparison to 1995.

   The average residence time in the forebay for spring/summer chinook hatchery juveniles in 1995 and 1996 were 2.0 days and 8.2 hours respectively. The decrease in forebay residence time could be a result of the higher river flow observed in 1996 or as a result of surface collector operations. More data will need to be collected in 1997 before conclusions can be drawn regarding the effect the SBC has on juvenile travel time.

5. Configuration C3 (2100 cfs, 2 fps, vertical openings) had the highest daily effectiveness relative to overall SBC and turbine discharge (units 4-6).

   In other words, the SBC operating at 2100 cfs (2 fps) passed about 8 times as many fish per cfs than turbine units 4-6. In addition the C3 configuration passed about 1.5 times as many fish per cfs than configuration C1 (3900 cfs, 6 fps, horizontal openings) and C2 (3900 cfs, 6 fps, vertical openings). These data may indicate that total system flow or entrance velocity may not be as important in fish guidance as opening size and location. Testing in 1997 should be focused on determining which configuration maximizes collection efficiency.

Cowlitz Falls

The testing of the Wells type surface collector at Cowlitz Falls Dam was scheduled to start on April 15, 1996. However, due to construction and flood related problems at the project, testing did not begin until May 30. By this time most of the juvenile outmigration was over. Because of the delay, FGE data were only available for steelhead and coho.

Hydroacoustics and mark-recapture techniques were used as the evaluation tools to determine the fish guidance efficiency of the entire juvenile bypass system and screened versus unscreened baffle slots. The hydroacoustic data will not be available until late September and therefore are not discussed in this report. The results of the 1996 mark-recapture tests are as follows:

1. Recapture efficiencies for coho and steelhead captured at the project and re-released upstream were 14.5 percent and 49.7 percent respectively.

   The steelhead data were similar to those collected at Lower Granite Dam which showed SBC efficiencies of around 40 to 50 percent for all species combined. The coho numbers were quite disappointing as researchers at the project expected the FGE for this

surface oriented species to be closer to 90 percent rather than the 14.5 percent observed. However, the handling and marking of the coho may have influenced study results. Coho released from a Merwin trap located about 0.5 miles upstream of the project had a guidance efficiency of 40.3 percent. These data demonstrate the need for selecting test groups and procedures that will accurately predict system effectiveness.

2. Turbine induction flow utilizes a venturi principal to draw surface (fish collector) water through the units. This design was used successfully to attract fish into the bypass system.

   The flow through the four entrance slots (baffles) was generated by opening the turbine slot covers downstream of each baffle. These slots send water into the units through screens instead of through the spillway to save energy. By removing the slot covers researchers were able to pull approximately five percent (250 cfs) of each turbine's discharge through a single baffle. The 250 cfs was used as 100% of the attraction flow for the system. This system, as well as the Rocky Reach Corner Collector, proves the theory that induction flow can be used instead of spill to operate surface collection systems.

3. The juvenile bypass system passed about 50 percent of the fish with ten percent of turbine discharge, a 5 to 1 ratio.

   This ratio was similar to the Lower Granite results which showed that the SBC passed 5-10 times more fish per unit of water than turbines 4-6.

Appendix B

RISK ASSESSMENT

Appendix B RISK ASSESSMENT

Risk Assessment through Life-Cycle and Passage Model Analyses

Risk assessment can be aided by reviewing life-cycle or river system passage model analyses. The models allow for the application of classic "what if" or sensitivity analyses that are often a key component within risk assessments. The impacts of different path alternatives can be estimated given specific variable assumptions and the presumed effectiveness of different path measures.

Salmon benefit estimates are derived from the models by determining survival rates for different life stages and physical points during migration. The models incorporate fundamental system features, such as high or low fish abundance or survival rates, based on available empirical data observations. While the available models range broadly in their degree of complexity, their results are relatively similar when consistent input variable assumptions are used.

For the risk assessment being developed within this study, the greatest utility of the model applications is to compare potential path measures during one downriver (or life-cycle) migration, not to attempt to forecast the date of a specific recovery goal across multiple life-cycles. Within the models, variable uncertainty does exist, and this uncertainty or resultant error is amplified when multiple migration cycle forecasts are considered.

Review of CRiSP 1.5 Model Analysis

The juvenile salmon passage model that is recognized by NMFS within the 1995 Biological Opinion as best representing available empirical data is the University of Washington CRiSP model. The CRiSP model describes downriver juvenile salmon survival in terms of several submodels that convey interactions for fish travel time, flow velocity, reservoir mortality, river system dam passage, predation levels within reservoirs, the effects of dis-

solved gas (nitrogen supersaturation) within the river, and smolt transportation through the river system. The CRiSP 1.5 model also incorporates recent data analyses conducted by a joint NMFS/University of Washington research team to develop improved data for flow regime-smolt survival relationships within the Snake River system. Other recent empirical data sets are used to calibrate the model as well.

The key results for several path analyses are displayed within the Summary Table for CRiSP 1.5 Model Runs and the Marginal Benefit Analysis table (more detailed analysis tables are also attached). Within these analyses, "baseline" conditions for hydro system operations reflect the 1995 BiOp operating regime, with the exception that flow augmentation is reduced to simulate "pre-ESA" operating conditions (no augmentation within the Snake or Columbia rivers). This is done in order to assess the incremental effects of flow augmentation, as an independent measure for salmon recovery. Low water conditions are based on the 1992 flow regime for the Snake-Columbia River system, and average water conditions are based on 1995 flow conditions. These model runs assess path alternatives for the spring chinook migration.

Several key observations are discussed below and refer to measure effectiveness under low water conditions, unless stated otherwise.

Transportation Path

1. The juvenile salmon transportation alternative can be measured according to assumptions about relative effectiveness. For example, if it is assumed that the transport to in-river ratios of survival (TIRs) accurately reflect existing empirical data sources for transportation program evaluations and in-river survival (NMFS and UW data), then a TIR above 1.6 to 1.0 (or greater) would be expected, and for modeling purposes, a survival rate estimate of 89 percent for transports spring/summer chinook is appropriate. Under these assumptions, an overall survival rate of 56.3 percent is observed for Snake River spring chinook.

2. But if it is assumed that either in-river survival conditions have dramatically improved or that transported fish are affected by substantial latent mortality caused by transport conditions, then a much lower survival rate should be employed for the analyses here, about 50 percent, reflecting no survival rate benefit to transported fish relative to in-river passage fish. Under these assumptions, an overall survival rate of 33.6 percent is observed for Snake River spring chinook.

3. If the TIRs for transportation are actually 1.6 or greater under current river conditions, then all other *In-River Path* measures, including Snake River drawdowns, will not exceed transportation benefits. The 1995 to 1996 transportation evaluations being conducted by NMFS are critical to verifying this observation.

4. Assuming that relatively higher TIRs exist, a surface collector at Lower Granite Dam with 80 percent FGE would increase survival by about 3.9 percent (56.3 percent to 60.2 percent). Adding a second surface collector at Little Goose Dam with 80 percent FGE increases survival from 60.2 percent to 60.8 percent.

5. With surface collectors in place at Lower Granite and Little Goose dams, with 80 percent FGE, less than four percent of the fish that entered the Lower Granite Reservoir would remain in the river below Little Goose Dam. This suggests that any additional salmon recovery measures employed below Little Goose Dam would have very little effect on improving survival.

6. The benefits of McNary transport are limited for Snake River spring chinook, increasing survival from about 56.3 percent to 56.7 percent (as an incremental measure).

Mixed Path

1. As a *Mixed Path* measure, the principal benefit of flow augmentation is to increase marginally the collection rate for transportation, for fish collected at the Lower Granite and Little Goose dam.

2. Flow augmentation of one MAF from the Upper Snake River increases survival from 56.3 percent to 56.8 percent. An additional .5 MAF increases survival to 58.9 percent.

3. With transportation at the Snake River projects activated, the effects of flow augmentation from the Columbia River system have little survival rate improvement on Snake River fish. Flow augmentation of 2.5 MAF from the Columbia River increases survival from 58.9 percent to 59.3 percent. An additional 2.5 MAF increases survival to 59.6 percent.

4. With or without transportation, flow augmentation benefits are limited and higher level flow augmentation levels produce very small benefits (decreasing marginal benefits). This suggests that the existing flow augmentation regime within the 1995 BiOp

could be reduced, with the monetary "savings" re-directed to other more beneficial measures.

In-River — No Transport or Reservoir Drawdown Path

1. The effects of reducing existing turbine mortality are limited based on CRiSP modeling (p. B-6). Under an *In-River Path*, reducing turbine mortality from seven percent to five percent increases overall survival from 36.3 percent to 37.3 percent.

2. For an *In-River Path* based on project spill, improvements to FPE must be accompanied by an effective control for gas supersaturation. If gas levels are allowed to reflect current project passage conditions, then gas effects will likely increase mortality substantially through the hydro system. This occurs under both low and average water conditions.

3. For an *In-River Path*, improving FPE from 70 percent to 80 percent or higher (without gas effects) produces relatively small incremental benefits. For example, FPE increased 70 percent to 80 percent increases overall survival from 38.9 percent to 39.4 percent; 90 percent FPE increases survival to 39.9 percent.

4. Under existing project conditions, in-river survival could be increased to about 41 percent, with FPE at 90 percent, no gas effects, and turbine improvements.

Reservoir Drawdown Path

1. The survival effects of a John Day Pool drawdown to MOP are very small, if measurable. With transportation in place, a MOP drawdown would produce no measurable benefit to Snake River fish (no transport at McNary), and about a .2 percent survival increase for Mid-Columbia fish. Without transportation, a MOP drawdown would produce about a .2 percent survival rate increase for Snake River fish.

2. A two-pool, "natural-river" drawdown on the Snake River, without any down-river salmon transpiration, would reduce survival from about 56 percent to 46 percent, if higher transportation TIRs exist. With transportation at Lower Monumental and McNary, it would increase survival from 56.3 percent to 56.5 percent.

3. A four-pool, "natural river" drawdown on the Snake River would provide about a 53.4

percent survival rate. By comparison, the existing 1995 BiOp, with higher TIR assumptions, would likely produce a higher survival rate, about 56.3 percent.

4. When compared to an *In-River Path* with 80 percent FPE and no gas effects, the four-pool drawdown alternative provides a higher survival rate: 53.4 percent compared to 39.4 respectively.

Marginal Benefit Analysis

1. The CRiSP 1.5 analyses for the path alternatives can be ranked relative to baseline conditions. This ranking serves to highlight further the importance of the TIR assumptions. The alternatives generally are grouped within two categories: (1) measures that enhance transportation effectiveness; and (2) in-river measures that reduce or eliminate the survival impacts of dam passage.

2. If the higher TIR assumption is correct, then the greatest survival rate improvements would be obtained from surface collectors at Lower Granite and Little Goose dams, working in conjunction with the transportation program.

3. If the higher TIR assumptions are incorrect or misleading given present-day *In-River* passage conditions or latent transport mortality, then the greatest improvement to survival would be gained from a four-pool drawdown within the Lower Snake River.

Decision Making for Path Choices

The CRiSP 1.5 model analyses clearly illustrate the importance of receiving additional transportation and in-river survival data, prior to committing to a path decision with essentially irrevocable consequences. No definitive path decision should be made until the work currently being conducted by NMFS to re-assess TIRs is completed.

The analyses also identify several actions that yield very little marginal benefit and their continued implementation should be reviewed relative to potentially more productive alternatives. This would include measures such as flow augmentation and passage improvement measures at the lower river projects.

Table B-1: Summary Table - CRiSP 1.5 Model Runs for Hydro System Path Review Analysis

Measure or Action	Juvenile Snake River Spring Chinook PERCENT SURVIVAL ABOVE LOWER GRANITE POOL TO ESTUARY Low Water Condition	Average Water Condition
Transportation Path:		
1995 BIOP (Transp. Survival 89%)	56.3%	59.9%
1995 BIOP (Transp. Survival 50%)	33.6%	31.5%
1995 BIOP with McNary Transport	56.7%	60.2%
Surface C. at LG-W-Transp. (70% FGE)	58.8%	62.3%
Surface C. at LG-W-Transp. (80% FGE)	60.2%	63.8%
Surface C. at LG-W-Transp. (90% FGE)	58.8%	62.3%
Surface C. at LG-LG-W-Transp (70% FGE)	59.2%	62.7%
Surface C. at LG-LG-W-Transp (80% FGE)	60.8%	64.4%
Surface C. at LG-LG-W-Transp (90% FGE)	62.1%	65.8%
Transportation—In-River Mixed Path:		
Flow Aug. Snake R. (.5 MAF)	56.4%	—
Flow Aug. Snake R. (1.0 MAF)	58.8%	—
Flow Aug. Snake R. (1.5 MAF)	58.9%	—
Flow Aug. Snake/Col. R. (1.5/2.5 MAF)	59.3%	—
Flow Aug. Snake/Col. R. (1.5/5 MAF)	59.6%	—
In-River—No Transport or Reservoir Drawdown Path:		
1995 BIOP FPEs, TurbineMortality 7%	36.3%	39.3%
1995 BIOP FPEs, Turbine Mortality 5%	37.3%	39/6%
FPE 70%, Turbine Mortality 5%, with Gas	37.4%	38.7%
FPE 80%, Turbine Mortality 5%, with Gas	23.1%	17.6%
FPE 90%, Turbine Mortality 5%, with Gas	4.1%	5.4%
FPE 70%, Turbine Mortality 5%, no Gas	38.9%	42.0%
FPE 80%, Turbine Mortality 5%, no Gas	39.4%	42.6%
FPE 90%, Turbine Mortality 5%, no Gas	39.9%	42.9%
Reservoir Drawdown Path:		
John Day Pool No DD MOP, with Transp.	56.7%	60.2%
John Day Pool DD MOP, with Transp.	56.7%	60.2%
John Day Pool No DD MOP, no Transp.	35.4%	36.1%
John Day Pool DD MOP, No Transp.	35.6%	36.3%
LG-LG DD Natural River, No Transp.	46.1%	48.5%
LG-LG DD Natural River, Transp. LM-McN	56.5%	59.8%
All Snake River Reservoirs DD, No Transp.	53.4%	56.6%

Low-water based on 1992 flow conditions.
Average water based on 1995 flow conditions.

Table B-2: Marginal Benefit Analysis for CRiSP 1.5 Hydro System Path Review Analysis

	Juvenile Snake River Spring Chinook Percent Survival Above Lower Granite Pool to Estuary	
Measure or Action	Low Water Condition	Marginal Benefit Rank % Change from Baseline
Surface C. at LG-LG-W-Transp. (90% FGE)	62.1%	5.8%
Surface C. at LG-LG-W-Transp. (80% FGE)	60.8%	4.5%
Surface C. at LG-W-Transp. (80% FGE)	60.2%	3.9%
Flow Aug. Snake/Col R. (1.5/5 MAF)	59.6%	3.3%
Flow Aug. Snake/Col R. (1.5/2.5 MAF)	59.3%	3.0%
Flow Aug. Snake R. (1.5 MAF)	58.9%	2.6%
Flow Aug. Snake R. (1.0 MAF)	58.8%	2.5%
Surface C. at LG-W-Transp. (90% FGE)	58.8%	2.5%
1995 BIOP FPEs, Turbine Mortality 5%	57.3%	1.0%
McNary Transport	56.7%	0.4%
John Day Pool DD MOP, with Transp.	56.7%	0.4%
John Day Pool No DD MOP, with Transp.	56.7%	0.4%
LG-LG DD Natural River, Transp. LM-McN	56.5%	0.2%
Flow Aug. Snake R. (.5 MAF)	56.4%	0.1%
1995 BIOP—Baseline Conditions	56.3%	0.0%
All Snake R. Reservoirs DD, No Transp.	53.4%	-2.9%
LG-LG DD Natural River, No Transp.	46.1%	-10.2%
FPE 90%, Turbine Mortality 5%, No Gas	39.9%	-16.4%
FPE 80%, Turbine Mortality 5%, No Gas	39.4%	-16.9%
FPE 70%, Turbine Mortality 5%, No Gas	38.9%	-17.4%
FPE 70%, Turbine Mortality 5%, with Gas	37.4%	-18.9%
John Day Pool DD MOP, No Transp.	35.6%	-20.7%
John Day Pool No DD MOP, No Transp.	35.4%	-20.9%
FPE 80%, Turbine Mortality 5%, with Gas	23.1%	-33.2%
FPE 90%, Turbine Mortality 5%, with Gas	4.1%	-52.2%

Low-water based on 1992 flow conditions.

Table B-3: CRISP 1.5 Model Runs for Hydro System Path Analysis

Cell Values are per cent Survival for Alternative Hydrosystem Operations

Action	Low Water Condition Snake	Low Water Condition Mid-Col	Average Water Condition Snake	Average Water Condition Mid-Col
Transportation Path:				
Standard fge's; No Transportation; Turbine mortality = 0.07% at all dams				
no transport	35.4	31.5	38.4	36.1
Standard fge's; Transportation at all dams (w/ and w/out McNary); Turbine mortaltiy set to 0.05% at all dams; Transport survival = 89%				
w/Trans. at McNary	57.5	36.5	61.0	40.9
w/out Trans. at McNary	57.1	34.5	60.8	39.6
Standard fge's; Transportation at all dams (w/ and w/out McNary) Turbine mortaltiy set to 0.07% at all dams. Transport survival = 89%				
w/Trans. at McNary	56.7	33.5	60.2	37.5
w/out Trans. at McNary	56.3	31.5	59.9	36.1
Standard fge's; Transportation at all dams (w/ and 2/out McNary); Turbine mortality set to 0.07% at all dams. Transport survival = 50%				
w/Trans. at McNary	33.1	28.3	35.3	33.7
w/out Trans. at McNary	33.6	31.5	35.6	36.1
Surface collectors at L. Granite and L. Goose; Transportation at all dams; Turbine mortality set to 0.05% at all dams				
fge = 90% at Granite and Goose	62.3	36.5	66.0	40.9
fge = 80% at Granite and Goose	61.1	36.5	64.7	40.9
fge = 70% at Granite and Goose	59.6	36.5	63.2	40.9
Surface collectors at L. Granite and L. Goose; Transportation at all dams; turbine mortality set to 0.07% at all dams				
fge = 90% at Granite and Goose	62.1	33.5	65.8	37.5
fge = 80% at Granite and Goose	60.8	33.5	64.4	37.5
fge = 70% at Granite and Goose	59.2	33.5	62.7	37.5
Suface collectors at L. Granite; Transportation at all dams; turbine mortaltiy set to 0.05% at all dams				
fge = 90% at Granite	61.9	36.5	65.5	40.9
fge = 80% at Granite	60.6	36.5	64.2	40.9
fge = 70% at Granite	59.3	36.5	62.9	40.9

Table B-3 (con't): CRiSP 1.5 Model Runs for Hydro System Path Analysis

Cell Values are per cent Survival for Alternative Hydrosystem Operations

Action		Low Water Condition Snake	Low Water Condition Mid-Col	Average Water Condition Snake	Average Water Condition Mid-Col
Suface collectors at L. Granite; Transportation at all dams; turbine mortality set to 0.07% at all dams					
fge = 90% at Granite		61.7	33.5	65.4	37.5
fge = 80% at Granite		60.2	33.5	63.8	37.5
fge = 70% at Granite		58.8	33.5	62.3	37.5
Transportation, In-River Mixed Path:					
Transportation at all dams; Turbine mortaltiy = 0.7% at all dams; Transportation survival = 89%					
Flow augmentation at:					
Snake	**Columbia**				
0 MAF	0 MAF	56.3	31.5	59.9	36.1
0 MAF	2.5 MAF	56.7	34.2	60.3	38.1
0 MAF	5.0 MAF	57.0	35.2	60.6	39.7
0 MAF	8.5 MAF	57.4	37.4	—	—
0.5 MAF	0 MAF	56.4	31.5	60.1	36.1
1.0 MAF	0 MAF	58.8	31.5	59.3	36.1
1.5 MAF	0 MAF	58.9	31.6	—	—
0.5 MAF	2.5 MAF	56.7	34.2	60.4	38.1
0.5 MAF	5.0 MAF	57.1	35.3	60.8	39.7
1.0 MAF	2.5 MAF	59.1	34.3	59.7	38.0
1.0 MAF	5.0 MAF	59.5	35.3	60.0	39.7
In-River, No Transport or Reservoir Drawdown Path:					
Standard fge's; No Transportation; Turbine mortality = 0.07% at all dams					
no transport		35.4	31.5	38.4	36.1
Nsat < 120% at Tailwater					
no transport		36.3	31.3	39.3	36.0
Nsat < 120% at Tailwaters and Nsat < 115% at Forebays					
no transport		36.3	31.2	39.3	35.8

Table B-3 (con't): CRiSP 1.5 Model Runs for Hydro System Path Analysis

Spill caps (kcfs) required to achieve Nsat conditions

Dam	Low Water Condition 120%[1]	Low Water Condition 115%[2]	Average Water Condition 120%[1]	Average Water Condition 115%[2]
Lower Granite	*	*	13.8	11.5
Little Goose	15.2	3.5	5.4	2.1
Lower Monumental	41.5	41.5	*	*
Ice Harbor	**	*	19.0	19.0
Wells	22.5	17.5	29.0	20.0
Rocky Reach	6.5	6.5	6.9	3.3
Rock Island	36.0	24.0	16.0	16.0
Wanapum	4.5	2.7	5.0	3.4
Priest Rapids	*	*	*	*
McNary	*	119.0	*	*
John Day	*	97.0	*	107.0
The Dalles	*	*	*	*
Bonneville	33.0	33.0	37.0	37.0

Cell Values are per cent Survival for Alternative Hydro System Operations

Action	Low Water Condition Snake	Low Water Condition Mid-Col	Average Water Condition Snake	Average Water Condition Mid-Col
In-River—No Transport or Reservoir Drawdown Path:				
Standard fge's; No Transportation; Turbine mortality = 0.05% at all dams				
FPE determined by model	37.3	34.5	40.4	39.6
FPE = 90%	4.1	34.1	5.4	38.9
FPE = 80%	23.1	34.4	17.6	39.3
FPE = 70%	37.4	34.5	38.7	39.6

Notes:
Spill efficiency is 1:1 at Lower Granite, Little Goose, and Ice Harbor
Spill efficiency is 1.2:1 at Lower Monumental (based on hydroacoustic data)

Table B-3 (con't): CRISP 1.5 Model Runs for Hydro System Path Analysis

Spill % required to achieve FPE's

Dam		FPE = 90%	FPE = 80%	FPE = 70%
Lower Granite	(fge = 56%)	.773	.545	.318
Little Goose	(fge = 60%)	.75	.5	.25
Lower Mo	(fge = 55%)	.648	.463	.278
Ice Harbor	(fge = 54%)	.783	.565	.348

Cell values are per cent Survival for Alternative Hydro System Operations

Action	Low Water Condition Snake	Low Water Condition Mid-Col	Average Water Condition Snake	Average Water Condition Mid-Col
In-River, No Transport or Reservoir Drawdown Path:				
Standard fge's; No Transportation; Turbine mortality = 0.05% at all damsNo Nsat mortality				
FPE determined by model	38.7	35.0	41.8	40.2
FPE = 90%	39.9	35.0	42.9	40.2
FPE = 80%	39.4	35.0	42.6	40.2
FPE = 70%	38.9	35.0	42.0	40.2
Reservoir Drawdown Path:				
Standard Model Parameters; John Day MOP Drawdown				
No John Day DD; No Transport	35.4	31.5	38.4	36.1
John Day MOP DD; No Transport	35.6	31.7	38.6	36.3
No John Day DD; Full Transport	56.7	33.5	60.2	37.5
John Day MOP DD; Full Transport	56.7	33.7	60.2	37.6
Reservoir Drawdown Path:				
Standard Model Parameters; Snake River Natural River Drawdowns				
LG&LG natural river DD; No Transport	46.1	31.5	48.5	36.2
LG&LG natural river DD; Transport @ Lomo and McNary	56.5	31.5	59.8	38.2
Natural River DD at all Snake Projects; No Transport	53.4	31.5	56.6	36.3

Appendix C

ECONOMIC COSTS

Economic Issues Related to Alternative Lower Snake River Juvenile Passage Strategies

The Current Analysis of Alternative Strategies

The Walla Walla District of the Corps of Engineers is currently examining a variety of alternatives by which to improve juvenile salmon survival past the four Lower Snake River hydroelectric projects. Potential strategies include dam modifications for reservoir drawdowns to spillway crest or natural river levels, improvements to existing juvenile bypass systems, modification of existing spillways, and installation of new bypass systems. These strategies are being examined as part of the Corps' ongoing *System Configuration Study*. During *Phase I* of the *SCS* the full range of options available to improve juvenile survival were screened to provide a final set of strategies for further evaluation. The present study (*Salmon Decision Analysis*) provides a critical evaluation of the biological benefits and related uncertainties for the options identified at the conclusion of *Phase I*. The *Decision Analysis* also includes an examination of selected recovery strategies suggested in other regional forums. The economic costs likely to be associated with the options are also examined; the cost estimates are based on extensions of the economic analysis prepared for the *Columbia-Snake System Operation Review (SOR)* prepared jointly by the Corps of Engineers, the Bureau of Reclamation, and the Bonneville Power Administration as well as on the analysis prepared for the *Phase I System Configuration Study*.

The present operations of the Lower Snake portion of the Columbia-Snake River system reflect the operational requirements laid out in the 1995 NMFS Biological Opinion. Current actions reflect a mixed operations strategy, combining juvenile transport with project spill to achieve the stated goal of 80% fish passage efficiencies at the Lower Snake projects. The current NMFS recovery plan is the basis from which future decisions regarding alternative regional recovery strategies will be evaluated. Therefore, the current system operation is considered to be the appropriate basis from which to measure the incremental fish benefits and economic costs associated with the alternative recovery options evaluated in the *Salmon Decision Analysis* for the *Lower Snake River Feasibility Study*.

A comparative analysis of the economic costs associated with the hydrosystem operations outlined in the 1995 NMFS recovery plan were prepared as part of the *System Operation Review*. The Preferred Alternative from the SOR represented the operational requirements of the recovery plan; incremental costs for the alternative were measured relative to 1992-93 hydrosystem operations. The current system operation defined for the *Salmon Decision Analysis* incorporates one significant modification to the operations specified in the SOR. A year-round drawdown of the John Day reservoir to minimum operating pool (MOP) was

included in the SOR alternative; this operation is excluded from the specification of current operations for the *Salmon Decision Analysis*. Consequently, all costs associated with operation of John Day at MOP are excluded from the current analysis, including costs related to project implementation, hydropower generation, recreation, and water supply. All cost figures presented for current operations have been adjusted accordingly. Economic costs for the SOR preferred alternative were estimated to be $152 million relative to 1992-93 system operations. Removing the John Day MOP adjusts the estimated incremental costs of the operating strategy downward to $125 million. The estimated economic costs of the SOR preferred alternative and the current system operation are presented in Table 1.

Table C-1
Economic Costs of Current Hydrosystem Operations, *$1,000,000*
$1996 average annual equivalents, measured as changes from 1992-93 System operations

Economic Cost	SOR Preferred Alternative	Current Operation [a] *Salmon Decision Analysis*
Project Implementation	$10.3	$0
Power	$116	$116 [b]
Reservoir Recreation	$25.9	$9.5
Navigation	$0	$0
Water Supply	c/	—
Total Economic Costs	**$152.2**	**$125.5**

a/ Current Operation exclude year-round operation of the John Day pool at MOP.
b/ The hydropower costs associated with the John Day MOP operation are currently being estimated by the Corps and should be available during August 1996. Removing the effects of the John Day drawdown will lessen the power costs for current operations.
c/ Economic costs for water supply are related to pump modifications required for drawdown of the John Day pool to MOP. These impacts are included in the cost estimates for project implementation.

The Salmon Decision Analysis

The set of structural modifications and operational alternatives evaluated in the SOR and SCS Phase I studies incorporated three principle means by which improvements to Lower Snake River juvenile salmon survival can be accomplished. These included: i) transportation of juvenile salmon from collection sites on the Lower Snake River for release below Bonneville Dam, ii) in-river migration strategies incorporating reservoir drawdowns, flow augmentation, and structural modifications to enhance dam passage survival, and iii) a combination of in-river and transportation strategies. The pathway analysis developed in this study will provide

input to the Corps as the agency considers the biological effectiveness of recovery options available to improve Lower Snake River juvenile salmon survival under each of these principle strategies. One of the primary objectives of the current *Salmon Decision Analysis* is to identify the final set of recovery actions to examine in the SCS Phase II feasibility analysis. The economic analysis previously conducted for several of the SOR and SCS Phase I alternatives provides a basis for examining the economic trade-offs associated with the potential recovery options.

This *Appendix* provides a critical review of the economic analysis and methodologies used to develop estimates of the economic costs likely to be associated with alternative strategies for enhancing Lower Snake juvenile fish survival considered in the *Salmon Decision Analysis*. The economic analysis is based on a synthesis of data and methods utilized in the SOR and SCS studies. Wherever possible, updated cost and value information was incorporated into the current analysis. Some original analysis was also developed. These modifications are discussed throughout this Appendix and are incorporated by reference in the economic section of the main text.

The SOR and SCS studies are reviewed briefly below. Key elements related to the economic analysis are noted. The review is followed by a discussion of the general framework used to evaluate the economic trade-offs associated with the alternative strategies. A more detailed discussion of the likely economic cost issues for five key river resource uses is also presented.

The Columbia-Snake System Operation Review

The *System Operation Review* was a comprehensive environmental analysis of alternative operations strategies for the Columbia-Snake River system. The study was a joint agency effort undertaken by the US Army Corps of Engineers, the Bureau of Reclamation, and the Bonneville Power Administration. The Columbia River system, extending 1,214 miles from its origin in the Canadian Rockies to its confluence with the Pacific Ocean, supports a wide range of environmental and economic uses. These uses place multiple and oftentimes conflicting demands on available water supplies and river system operations. In response to the need to manage these competing uses, the three agencies responsible for various aspects of the river system began a review of future strategies for multi-purpose river operations.

Through a joint evaluation framework, the managing agencies sought to find a coordinated solution for future system operations that would better meet the demands of all environmental and economic river uses. The *System Operation Review* began in 1990 to address the potential strategies for multi-purpose operations. In 1991 however, the Snake River sockeye salmon was listed by NMFS as an endangered species under the ESA legislation. The Snake River spring/summer and fall chinook salmon were also listed under the legislation, first as threatened species in spring 1992 and later as endangered stocks in August 1994. The ESA listings shifted the focus of the SOR from an evaluation of alternative multi-use strategies to a

more direct focus on alternative operations to protect and enhance anadromous fish survival, with a particular emphasis on the three listed Snake River runs.

The ESA requirements that the Columbia-Snake River system be operated to avoid jeopardy to the endangered salmon and to protect their necessary habitat has long-term implications for the river environment available for other resources.[1] The operational alternatives evaluated throughout the screening, draft, and final phases of the SOR provided opportunities to examine the conflicts and trade-offs among system uses. River-based resources evaluated in the study included (in addition to anadromous fish) water quality, flood control, resident fish, wildlife, power generation, navigation, reservoir recreation, irrigation/M&I water supply, and cultural resources. The optimum river conditions for each of these river uses is presented in Table 2. Finding a way to balance the environmental and economic demands for these resources was one of the primary objectives of the SOR.

Table C-2
Optimum River Conditions for Competing River Uses

River Resource	Optimum River Conditions
Anadromous Fish	Streamflows as close to "natural" river conditions as possible, with mainstem reservoirs below spillway levels.
Cultural Resources	Stable reservoir elevations year-round.
Flood Control	Reservoirs drafted in early spring to capture snowmelt.
Irrigation	Full reservoirs April through October.
Navigation	Reservoirs at or above minimum operating pool.
Power Generation	Reduce or eliminate nonpower operating constraints on hydrosystem operations.
Reservoir Recreation	Full reservoirs May through October and stable downstream flows.
Resident Fish	Stable reservoirs year-round with natural river flows.
Water Quality	Natural river flows with minimum spill.
Wildlife	Stable year-round reservoir drawdowns to expose maximum acreage for long-term habitat recovery.

Source: *Columbia River System Operation Review, Final EIS, Main Report*, page 4-2.

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1 / The Kootenai River white sturgeon was listed by the US Fish and Wildlife Service as an endangered species in June 1994. Operations at Libby Dam must also take into account the protection of this species.

The *System Operation Review* considered a wide range of operational alternatives for the Columbia-Snake River system. The alternatives reflected varying combinations of management objectives for the environmental and economic river resources. Each potential operating strategy included a set of coordinated actions for all of the federal projects along the Columbia and Lower Snake rivers; some were designed to optimize system operations for power production, others for reservoir recreation or anadromous fish. Ninety alternatives were initially included in the screening phase of the SOR. The set was narrowed to ten distinct strategies in the draft study and further reduced to seven for the final analysis, including:

- SOS 1: Pre-ESA Operation. Reflects system operations as they existed prior to the ESA listings for the Snake River salmon in 1992. This strategy has two options.
- SOS 2: Current Operations. System operations as the existed in 1992 and 1993. Incorporates interim recovery actions recommended by NMFS in 1994. The strategy has two options, one of which (SOS 2c) was defined as the No-Action or base case alternative for the SOR.
- SOS 4: Stable Storage Project Operation. Operations designed to provide optimum benefits to reservoir recreation, resident fish, and wildlife. The strategy has one option.
- SOS 5: Natural River Operation. Drawdown of the Lower Snake River reservoirs to natural river levels in order to aid juvenile salmon migration. The strategy has two options.
- SOS 6: Fixed Drawdown. Drawdown of one or all of the Lower Snake River reservoirs to near spillway-crest levels in order to aid juvenile salmon migration. The strategy has two options.
- SOS 9: Settlement Discussion Alternatives. Strategies suggested by federal and state fisheries managers to optimize system operations for anadromous fish benefits. The strategy has three options.
- SOS PA: The Preferred Alternative. System operation recommended by NMFS in the 1995 Biological Opinion for recovery of the endangered Snake River salmon stocks. The strategy has one option.

Operating strategies incorporating the natural river and fixed drawdown alternatives have been incorporated into the *Salmon Decision Analysis* and are currently under evaluation by the Corps as possible options to improve Lower Snake juvenile survival. The mixed operations strategy examined in the SOR preferred alternative is also incorporated into the decision analysis.

The System Configuration Study

The *System Configuration Study* (SCS), initiated in 1992 by the US Amy Corps of Engineers, is a long-term evaluation of possible structural alternatives to improve adult and juvenile salmon migration in the Lower Snake and Columbia Rivers. The study was constructed in two parts. Phase I was comprised of a reconnaissance-level examination of the technical feasibility, biological effectiveness, and economic effects of a variety of structural improvements to aid with salmon recovery. Both near-term and long-term solutions were examined. The following options were evaluated in Phase I:

- Annual drawdown of the four Lower Snake reservoirs (22 different drawdown options were considered);
- Drawdown of the John Day reservoir;
- Development of additional water storage reservoirs on the Upper Snake River to support flow augmentation targets;
- Construction of a collector facility in the upper portion of Lower Granite reservoir; and
- Structural improvements to existing bypass and transportation collection facilities at the Lower Snake and Columbia River projects.

The drawdown options examined in the SOR (SOS 5 and SOS 6) were based on alternatives developed in Phase I of the SCS. The natural river alternative included a four and one-half month drawdown option and a permanent drawdown scenario; this latter option was not included in the SCS but was added to the SOR after extensive public comment was received on the Phase I study.

Several of the options evaluated in Phase I were recommended for further examination in the Phase II portion of the SCS, which is currently underway. In the second stage of the study, a detailed feasibility-level examination of the recommended set of structural modifications and improvements will be made. It is expected that the results from this phase will be used for Congressional authorization and funding of specific actions to support salmon recovery on the Columbia-Snake River system.

The General Framework for Economic Evaluation

The direct economic effects of the alternative pathway options for the Salmon Decision Analysis are measured in terms of changes in the value of commodities and activities directly affected by the river operations strategies. National Economic Development (NED) guidelines and principles are used to measure the direct economic costs and benefits associated with the alternative strategies. The basis for the NED procedures is to determine whether the benefits associated with alternative river operations exceed the costs associated with the revised operations. However, the measurement of direct impacts is complicated by the fact that expected changes to some of the river-based activities are measured in terms of non-marketed biological or physical outputs rather than economic values (e.g., anadromous fish, recreation). In these cases, the value of changes in physical output are approximated using willingness-to-pay measures which quantify the amount of money an individual would be willing to pay for the expected changes in physical output. The methodologies used in the current analysis are consistent with those developed for the SOR and SCS studies.

The primary economic activities that would be affected by the structural and operational changes required under the Lower Snake pathway alternatives include hydropower generation, reservoir recreation, commercial barge navigation, and irrigation and municipal water supply.[2] A brief description of the direct measures of economic change for the opportunity costs and project implementation costs are presented in Table 3.

The benefits and costs to each of the affected resource activities, including the project costs to implement the operations strategy, are computed and summed for each alternative. Results are compared to the base case to determine the incremental economic costs associated with the alternative. The measurement of net gain or net loss is from a national perspective and does not take into account any differences in regional, state, and local area gains and losses that may result.

Time Frame for Evaluation

A shift in operating strategies for the Columbia-Snake River system will necessarily result in long-term changes to the activities and environments of the region's river-based resources. The magnitude of the economic impacts associated with the modified operations depend, in part, on the length of time required to fully implement the revised plan. Strategies which require longer

2 / Analysis developed for the SOR and the SCS studies indicated that the recovery options being examined in the *Salmon Decision Analysis* are not likely to result in significant changes in the economic costs related to flood control. Therefore, these costs were not considered in this analysis.

time periods to carry out (e.g. extensive dam modifications) will not result in economic changes for many years, as compared to a strategy that can be implemented without delay. In order to compare the economic trade-offs for operating strategies with different implementation dates, the values must first be expressed for comparable points in time.

Table C-3
Economic Measures Used to Value Expected Changes in River Uses

Resource Activity	Measure of Direct Economic Impact
Project Implementation	Construction costs associated with project implementation requirements, including investment costs, interest during construction and annual operations and maintenance..
Hydropower	Changes in regional power costs, including system operations costs and new resource costs.
Reservoir Recreation	Changes in recreation visits and the associated willingness-to-pay values for reservoir recreation activities under alternative reservoir operations.
Navigation	Changes in commodity shipping costs related to changes in shipping routes and shipping modes under alternative reservoir operations
Irrigation and Municipal Water Supply	Changes in pumping costs related to necessary pump modifications, increased operation and maintenance costs, and increased energy costs.

The discount rate is used to translate future economic costs to their equivalent value in the current time period. This can be illustrated by looking at two operating strategies that result in the same level of economic costs. However, one strategy can be implemented immediately whereas the other requires ten years for structural modifications before operations can be changed. When expressed in present day terms the latter strategy actually costs less. For example, two possible strategies result in average annual economic costs of $1 million. Plan A can be placed in operation today while plan B requires 10 years to complete. The $1 million costs associated with plan B are not realized for 10 years. With a discount rate of 5%, the

current value of the plan B costs are adjusted to $614,000.[3] This would compare to the plan A current value cost of $1 million. These current cost estimates are referred to as annual equivalent values since costs expected to occur at different points in time have been re-expressed to a common time frame. These equivalent costs can be included with other factors describing the environmental outcomes of both strategies to assist decision-makers in the selection of one plan over the other.

The economic effects of the alternative pathway strategies were compared over a 100-year time frame. This time frame recognizes the significant time period that may be required for the recovery strategies to be effective in stabilizing long-term survival for the Lower Snake salmon. Because the alternative strategies have different implementation dates, economic effects over time are discounted using a federal project discount rate of 7.75%. Constant prices are assumed throughout the evaluation period, using a 1996 base year. The economic impacts are presented in terms of average annual equivalent values, which take into account the time distribution of the impacts. This framework is consistent with the economic analysis developed for the SOR and SCS studies.

Measuring Economic Trade-offs

Recovery of the Snake River salmon and protection of their natural environment will yield significant environmental, cultural, and economic benefits to the region. In some cases, recovery efforts will yield tangible benefits: increased survival will lead to larger numbers of fish which in turn will support higher levels of sustained harvest opportunities for commercial, recreational, and cultural uses. Intangible benefits include the preservation of biological diversity, the protection of river habitat, and the protection of Native American cultural values. The *Lower Snake Salmon Decision Analysis* considers only the biological benefits associated with alternative pathway options. No attempt is made to measure the associated economic benefits, since recovery objectives do not require an analysis of these effects. Economic trade-offs are presented in terms of the economic costs required to achieve alternative levels of biological benefits.

Economic costs condifered in the Salmon Deciosion Analysis for the Lower Snake river include project implementation costs, regional power system costs, reservoir recreation values, shallow draft navigation costs, and pumping costs for irrigation and municipal/industrial water supplies. Methodological issues and estimated values for each of these economic costs are descrived in the following sections.

3/ Using a higher discount rate leads to lower current value estimates of future costs. A lower discount will result in higher current value estimates.

Project Implementation Costs

Many of the alternatives evaluated for the SOR and all of the alternatives examined in Phase I of the SCS included the implementation of improvements and/or modifications to existing hydroelectric projects and fish passage facilities. A variety of structural modifications to the existing Lower Snake projects were evaluated for potential improvements to juvenile fish passage during the downstream migration period. Alternatives evaluated for passage improvements included fixed-level and natural river drawdowns of the four Lower Snake pools and structural enhancements to reduce mortality at the dams (e.g. surface collectors and extended length screens). Improvements to the juvenile fish transportation program were also examined, with options ranging from the addition of new barges to the design and construction of an upstream collector system to be located at Lower Granite reservoir.

Implementation of any of these options would require additional expenditures for project development, as well as expenditures for annual operations and maintenance. Many of the subpaths examined in the *Salmon Decision Analysis* include one or more structural additions or modifications to the existing Lower Snake projects in order to implement the proposed in-river or transportation strategy. To the extent possible, the implementation costs likely to be associated with these alternative subpaths have been incorporated into Economic Costs Section of the *Salmon Decision Analysis*.

Project implementation costs are defined as all costs that would be incurred to modify the existing Lower Snake projects in order to realize the passage improvements in a manner consistent with the criteria laid out in the pathways. The costs would include construction expenditures for modification of existing structures or development of new structures; costs to mitigate adverse impacts to other public and private facilities, cultural resources, and fish and wildlife resources; the costs of project planning and engineering; and the costs for construction management. Implementation costs also take into account the opportunity cost of the funds utilized for project development throughout the construction period. The opportunity costs, referred to as 'interest during construction' in Corps of Engineers cost schedules, are considered a relevant project cost since they represent the foregone benefits of an alternative public investment that could have been made with the committed funds.

The implementation costs prepared for Phase I of the System Configuration Study represent reconnaissance-level estimates of the expected costs for the alternatives examined in the study. The costs are considered useful for comparative purposes, but would require a more detailed feasibility analysis before determining necessary appropriations levels.

Implementation costs for the juvenile passage improvements examined as part of the Salmon Decision Analysis are summarized below. Estimates are provided for total construction costs, average annual costs (annualized investment costs plus annual O&M costs), and average

annual equivalent costs. The latter costs represent the average annual costs computed to a common point in time to allow for a comparison of projects with differing implementation time requirements. All project costs have been adjusted to 1996 dollars.

Implementation Costs for Drawdown Alternatives

Four of the Lower Snake drawdown alternatives examined in the SCS Phase I were also incorporated into the final analysis for the System Operation Review. These include a four and one-half month drawdown of the four projects to natural river levels (SOS 5b), a permanent year-round natural river drawdown at the four projects (SOS 5c), a four and one-half month spillway crest drawdown at the four projects (SOS 6b) and at Lower Granite only (SOS 6d). These alternatives have also been incorporated into the Salmon Decision Analysis. A fifth drawdown option is also considered in the current analysis. The alternative includes a two-pool permanent natural river drawdown of the Lower Granite and Little Goose reservoirs. A brief description of the project modifications necessary for each of these alternatives is provided in Table 4. Implementation costs for the drawdown alternatives are presented in Table 5; figures include total project costs and average annual equivalent costs.[4]

Table C-4
Project Modifications Necessary to Implement Drawdown

Drawdown Alternative	Description of Modifications
Seasonal Natural River Drawdown Requires 15 years to implement	Requires a new controlled bypass channel and related features; modifications to adult fish passage facilities.
Permanent Natural River Drawdown *(two or four pool)* Requires 5 years to implement	Removal of dam embankments to create a permanent channel around the projects.
Seasonal Spillway Crest Drawdown Requires 10 years to implement	Modifications of the stilling basins; adult and juvenile passage facility modifications.
Seasonal Spillway Crest Drawdown *(Lower Granite only)* Requires 5 years to implement	Structural changes limited to upstream forbear side of the project; modifications to adult and juvenile passage facilities.

4 / A more detailed presentation of implementation costs for the drawdown alternatives is presented in Attachment C1.

Table C-5
Implementation Costs for the Lower Snake Drawdown Alternatives
Cost Figures in $1996, ($1,000,000)

Drawdown Alternative	Construction Cost	Average Annual Cost	Equivalent Annual Cost
Seasonal Natural River	$3,588	$515	$168
Permanent Natural River			
Four Pool	$543	$53	$36
Two Pool	$271	$26	$18
Seasonal Spillway Crest			
Four Pool	$1,033	$120	$57
Lower Granite Only	$79	$8	$5

Source: System Configuration Study, Phase I, Appendix A and Columbia River System Operation Review, Appendix O.

Potential System Improvements

Phase I of the System Configuration Study included reconnaissance-level evaluations of several alternatives that considered modifications or improvements to existing facilities to enhance downstream migration for juvenile fish.[5] The alternatives considered both improvements to existing juvenile fish bypass and collection systems to improve fish passage through the dams and spillway/stilling basin modifications to reduce dissolved gas saturation levels for spill-related operations. Juvenile bypass system and fish passage improvements evaluated during Phase I included the following:

- Extended length turbine screens to improve fish guidance efficiencies (currently installed at Lower Granite and Little Goose, and proposed for Lower Monumental and Ice Harbor);
- Modification of existing Lower Granite fish bypass facilities to state-of-the art configurations, including an open channel collector and a new wet separator to improve juvenile passage;

5 / *Improvements to the Existing Systems Technical Report, Appendix E*, Columbia River Salmon Mitigation Analysis, System Configuration Study, Phase I, US Army Corps of Engineers, Walla Walla District, April 1994.

- A surface-oriented fish collection and bypass system at Lower Granite designed to significantly improve fish guidance efficiencies and to provide flexibility in operational alternatives; and

- Installation of elevated stilling basins as a potential means of reducing dissolved gas saturation levels.

Several improvements to the existing transportation program were also examined in Phase I of the SCS. Many of the items considered were incorporated into the 1995 BiOp and have been or will be implemented in the next few years, including enlarge barge exits and the addition of new barges to the transportation program. The potential use of a large-scale upstream collector as a means of significantly increasing collection rates was also examined. However, because of the considerable expense associated with this option, it has been eliminated from further evaluation as a viable pathway alternative.

A surface collector prototype is currently being tested at Lower Granite Dam. Final construction of the prototype is expected to be completed in 1997. Construction costs for the prototype have been estimated at $18.7 million. Installation of dewatering screens in the collector would increase construction costs to $25 million. The addition of screens would enable the surface collector to be used in conjunction with the juvenile transportation program.[6]

Under current operations of the Lower Snake system, significant amounts of project flow are passed over the spillways in order to guide juvenile fish away from the generating turbines. High levels of project spill can lead to unacceptable concentrations of dissolved gases. Spillway baffles have been proposed as a means of reducing the amount spill required to pass fish over the projects. By reducing spill and associated gas levels, baffles have the added advantage of reducing the losses in hydropower revenues associated with the spill. Spillway baffles have been recently installed at The Dalles Dam and at Grant County PUD's Wanapum Dam. Construction costs for installation of baffles at the Lower Snake projects are estimated at $500,000.[7] It is expected that one to three baffles would be required at each project.

The estimated implementation costs for system improvements under consideration in the current pathway analysis are presented in Table 6.[8] As cautioned in the SCS Phase I report,

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6 / Personal communication, Corps of Engineers, Walla Walla District, Spring 1996.

7 / Personal communication, Harza Northwest, Inc., Spring 1996.

8 / A more detailed presentation of project implementation costs for various system improvements in presented in Attachment C1.

the costs reflect reconnaissance level estimates and are useful for comparative purposes only. Final decisions regarding actual implementation of these alternatives at one or more of the Lower Snake projects would require a more detailed study of engineering and design costs.

Table C-6
Implementation Costs for Potential System Improvements
Cost Figures in $1996, ($1,000,000)

System Improvement	Construction Cost	Average Annual Cost	Years to Implement	Equivalent Annual Cost
Surface Collector *from SCS Phase I*	$124	$11	3	$8.7
Screened Surface Collector *from Lower Granite Prototype*	$25	$2.3	3	$1.9
Unscreened Surface Collector *from Lower Granite Prototype*	$18.7	$1.8	3	$1.4
Extended Length Screens	$26	$2.3	3.5	$1.8
Enhanced Bypass System	$22	$2.2	5	$1.5
Elevated Stilling Basin	$38	$3.8	6.5	$2.4
Spillway Baffles	$0.5	$0.04	1	$0.04

Source: System Configuration Study, Phase I, Appendix E, Improvements to Existing System Technical Report, and Appendix F, System Improvements Technical Report, Lower Columbia River.

Regional Fish and Wildlife Program Costs

The estimates for project costs do not incorporate any potential changes to funding levels in the current regional anadromous fish program that may result with long-term implementation of alternative downstream passage strategies. Potential differences in the Corps of Engineers' research, monitoring, testing, and evaluation programs have also not been examined for any of the alternative pathways.

Regional Power System Costs

Electric power in the Pacific Northwest is generated by a variety of resources including hydropower, coal-fired power plants, combustion turbines, nuclear power, industrial cogeneration, and a variety of renewable resources. Hydropower is the region's most significant source of production, providing approximately 11,740 average megawatts (aMW) of firm energy annually. This accounts for two-thirds of the current generating potential *(see Table 7)*. Firm energy is the maximum amount of energy that can be generated under hydrologic conditions comparable to the driest period on record. In average water years the hydropower system generates an additional 4,000 average megawatts (aMW); this additional supply, known as nonfirm energy, is not included in long-term resource planning because of the uncertainty regarding its availability. In years when nonfirm energy is generated, higher cost generating resources can be temporarily taken out of production or the power can be sold to out-of-region buyers under short-term contracts.

Table C-7
Electric Generating Resources in the Pacific Northwest

Generating Resource	aMW	% of Total
Hydropower	11,740	67%
Coal	3,280	19%
Natural Gas	1,150	6%
Nuclear	780	4%
Renewable Resources	650	4%
Total	**17,600**	**100%**

Source: Northwest Power Planning Council, *Northwest Power in Transition: Opportunities and Risks, Draft Fourth Northwest Conservation and Electric Power Plan*, Report 96-5, March 1996.

The Shifting Focus of Hydrosystem Operations

Nearly two hundred hydroelectric projects have been developed for power generation throughout the Columbia-Snake River basin. More than half of these have generating capacities of ten megawatts or more, contributing significantly to the region's hydropower resource base. Thirty projects are federally-owned and operated; twenty-one of these are maintained by the Corps of Engineers and the remaining nine are operated by the Bureau of

Reclamation. The power analysis prepared for the SOR and SCS studies focused on operations at the fourteen federal projects located on the Columbia and Lower Snake Rivers.[9] These projects account for ninety-seven percent of total federal hydropower capability and nearly sixty percent of total regional electric generating capability.

The natural flow of the Columbia-Snake River system peaks in the spring and early summer when melting snowpack moves into streams and tributaries, increasing overall flows three- and four-fold over wintertime levels. As the river system was developed for hydropower, storage dams were placed on the upper reaches of the Columbia-Snake system to hold back these natural flows. This allowed for regulated water releases in fall and winter to better match energy production with regional power demands. Traditionally, power project managers have operated the hydrosystem to expand the system's firm energy capabilities; optimize the system's annual power production through project refill and storage actions; and maximize the system's production of non-firm energy to help offset overall regional power costs.

Although many factors are considered to have contributed to the decline in Snake River salmon stocks, shifting river system flows from spring and summer to fall and winter, while beneficial to power production, has had adverse impacts on anadromous fish migration. Beginning in the early 1980s, with passage of the Northwest Power Act and the advent of the region's first Fish and Wildlife Program, increasing emphasis has been placed on modifying operations of the river system to allow for improved fish passage, particularly during the spring juvenile migration period. A key factor in these modified operations has been to release water from storage during spring and summer to allow fish to pass more rapidly through the hydropower system. This effectively reduces the amount of energy that can be generated in the fall and winter using stored water. Spill operations have also been used as a means of aiding juvenile fish in moving past the hydro-projects. With spill, large amounts of water are passed over project spillways rather than through project turbines, thereby significantly reducing fish passage mortality at the dam sites.

Current Operations Under the 1995 Biological Opinion

As a consequence of the hydrosystem operations required under implementation of the 1995 NMFS Biological Opinion, the Bonneville Power Administration is moving toward a new approach to long-term resource planning. Prior to requirements under the current Biological Opinion, BPA utilized a traditional least cost planning approach with which to target and evaluate new resource development. The analysis was based on expected annual load/resource

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9 / The remaining federal projects are located in the Willamette Valley the Yakima Valley and in the upper Snake River basin. The operational influence of these projects on power coordination along the Columbia and Lower Snake Rivers was considered to be relatively small (*SOR, FEIS, Main Report*, p. 1-7).

balances generated under storage-based hydrosystem operations. Current operations have shifted from storage-based to flow-based operating criteria which has led to a consequent shift in BPA's new resource planning strategy. The agency's current new resource acquisition strategy is to rely on power market purchases to meet anticipated monthly energy deficits.

Measuring Power Costs

Any changes in Columbia-Snake river operations to improve juvenile fish passage during downstream migration are likely to affect the timing and quantity of electrical power generated by the hydrosystem. Following the analysis developed for the SOR and SCS studies, power system impacts in the current pathway analysis are measured by the changes in the capability of the regional power system to provide energy and capacity to meet regional demands.[10,11] The ability of the system to produce firm energy depends on the flexibility to store water in the spring and summer for later release in the fall and winter when electricity demand in the Pacific Northwest is greatest. When the hydrosystem is unable to generate sufficient energy and capacity, additional resources must be purchased so that regional power demands can be met. Conversely, hydropower generated with increased flows provided for juvenile fish passage may exceed regional power demands. The surplus (nonfirm) power is generally sold under short-term contracts to out-of region buyers at prices commonly below those that must be paid for additional power during the fall and winter.

Total power system impacts are established by looking at the cost of providing regional energy supplies, sustained capacity (the system's ability to produce 50 hours per week of daytime capacity under critical water conditions) and instantaneous capacity (system's ability to meet a one-hour peak during critical water conditions). These power costs, referred to as gross system replacement costs, include the operating costs for all resources (hydro and otherwise), the capital costs for new resource acquisitions, less the revenues generated by out-of-region sales of excess nonfirm power produced by the regional system. The analysis of power system impacts takes into account monthly loads, total generation from the existing hydro- and thermal system, operating costs and maintenance schedules for the thermal plants, new resource costs and acquisitions, prices for out-of-region sales, and prices for purchased energy. Where possible, existing thermal resources are displaced by lower cost market purchases and new resource acquisitions.

10/ The power system impacts for the SOR and SCS studies were prepared by the Bonneville Power Administration, in cooperation with the Corps of Engineers and the Bureau of Reclamation.

11 / Energy is measured as average power production over time while capacity is the maximum sustainable amount of power that can be produced over a short duration of time. Both power resources are taken into account for short-term and long-term planning purposes.

Power system costs were adjusted to account for the effects that potential increases in power rates would have on consumer demand. Changes in the least-cost resource mix necessary to meet forecasted regional loads would cause average wholesale power rates to increase. As power rates adjust upward, regional consumers are likely to use less electricity. The reduction in regional power demand will adjust downward the level of additional resources required to meet loads. This leads to continued rounds of adjustments to resource mix, electricity requirements, and consumer demand until a supply-demand balance is achieved. To account for the iterative effects of the equilibrium process, a first-round adjustment was estimated to determine the effects of the changes in gross system power costs on regional power demand. Power costs were re-estimated using the adjusted power demand. These revised power cost estimates, referred to as net system replacement costs, represent the final estimates of power impacts related to alternative structural and operating strategies.

Uncertainty Considerations

A variety of factors can affect the magnitude of the regional power impacts. The most important source of variability in the estimated impacts is the year-to-year fluctuations in power production related to annual variations in rainfall and snow pack. In addition, regional energy loads, fuel costs, out-of-region energy and capacity prices, and new resource costs must be projected out many years into the future. This leads to uncertainties in the long-term forecasts for regional power demand and future resource costs.

Because annual generation and future loads and prices cannot be known with certainty, the impacts of alternative operations can be estimated with a range of values for each of the uncertain factors. During the screening phase of the SOR power analysis it was determined that only the variability associated with annual hydro-generation capabilities significantly affected the estimated power impacts. Therefore, the analysis incorporated into the final power studies prepared for the SOR accounted only for the variation in water availability. For each operations alternative, power system impacts are evaluated for separately for each of the fifty water years of record; annual power system costs for alternative strategies reflect the average annual impacts over the fifty water year types.

New Resource Acquisitions

Traditionally, the decision to acquire new generating resources to meet regional power demands has been based on a comparison of average annual loads and resources. As long as available resources were sufficient to meet average loads, it was assumed that the hydrosystem could be operated to fill in any daily and monthly deficits that might occur. If loads were projected to exceed resources, new resources were identified for acquisition until the average annual load-resource balance was restored.

However, the flexibility of the hydrosystem to meet these short-run load deficits is limited with current operations under the 1995 Biological Opinion. Operational flexibility was also limited under many of the other alternatives considered in the SOR and SCS studies, particularly those which establish fish flow targets on the Lower Columbia and Lower Snake rivers.

With the new competitive environment in the Pacific Northwest electric utility industry, the emphasis in resource acquisition decisions has shifted away from project development to a greater reliance on market purchases. Power planners at BPA expect this trend toward greater reliance on market purchases to continue with future resource decisions until such time that utility system reliability declines to the point where firm resource acquisitions become necessary or until the cost for new resources becomes competitive with market purchases.[12]

The power system analysis developed by the Bonneville Power Administration assumed that new resource decisions would be based on the following:

- Regional utilities would continue current measures of system reliability which limits probability of failure to meet loads to one day in twenty years (or 1.2 hour per year);

- New resource requirements would first be met by out-of-region purchases up to the limit of current intertie capacity; and

- Thereafter, additional new resources would be constructed. Combined cycle combustion turbines (CTs) were considered to be the most cost-effective resource alternative.

The quantity of additional resources acquired alternative operating strategies is determined through an exhaustive set of simulations that take into account a variety of system uncertainties including intertie availability (based on historical outages), thermal plant performance, regional loads, and available hydrogeneration (based on the historical water record). Monte Carlo simulations with additional levels of resource acquisitions were run until load failures converged at the targeted level. The cost of these additional resources are incorporated in the analysis of power system impacts.

Improvements in Methodology

The methodology used to estimate regional power cost impacts for the final SOR incorporated several revisions to the methods used in earlier analyses. The revisions were based, in part, on regional comments received on the draft EIS as well as on internal agency review and

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12/ Columbia River System Operation Review, Final Environmental Impact Statement, *Appendix I, Power*, November 1995.

methodological improvements. Changes included the incorporation of monthly price variations for purchased power and non-firm energy sales; improved price estimates for purchased power and non-firm energy sales; and the displacement of thermal resources prior to the lower cost CT resources.

Since the economic analysis for hydropower was completed for the SOR, West Coast market prices for energy and capacity have continued to decline. Prices are expected to remain low for at least the next eight to ten years.[13] Thereafter, the region will move closer to load-resource balance and market prices can be expected to shift upward. If these lower prices had been incorporated into the regional power analysis estimated impacts would be somewhat lower than those presented in the SOR Final EIS.

Estimating Power Impacts for the Salmon Decision Analysis

Hydropower impacts related to the alternatives being evaluated in the Salmon Decision Analysis are currently being estimated by the Corps of Engineers in cooperation with the Bonneville Power Administration. It is expected that these estimates will be available in the Fall of 1996. The power analysis currently underway is being developed using the Corps's hydrosystem simulation model, HYSSR. System generation output from the HYSSR model will be incorporated into BPA's power cost spreadsheet model (developed for the SOR and other studies). The power cost analysis will provide the expected changes in system power costs relative to current 1996 operations under the NMFS Biological Opinion. A variety of Lower Snake juvenile salmon recovery options are being examined, including seasonal and permanent natural river drawdowns, seasonal spillway -crest drawdowns, John Day drawdown to minimum operating pool (MOP), Lower Snake reservoir drawdowns to MOP. The analysis will also examine the power costs associated with a variety of options to achieve eighty percent fish passage efficiencies at the Lower Snake projects. The revised power costs analysis being prepared by the Corps will incorporate the more current West Coast market prices and energy and capacity price forecasts.

For purposes of presentation in this document, the power system analysis relies on the earlier studies prepared by the Bonneville Power Administration for the SOR Final EIS. Expected changes in system power costs are measured relative to the SOR preferred alternative.

13 / Northwest Power Planning Council, *1996 Northwest Power Plan*.

Incorporating Power System Impacts from the SOR

For the operational scenarios evaluated as part of the SOR, power cost impacts were found to be most significant under the mixed operations strategies (combinations of spill, flow targets, and mid-level drawdowns) and under the permanent natural river drawdown option The expected changes in power costs reflect the overall change in hydrosystem management necessary to meet the operational criteria specified in the alternatives. The economic analysis for hydropower costs incorporated two market scenarios, one reflecting conditions in 1996 and one reflecting expected conditions in 2004. This allowed the analysis to incorporate modest increases in energy and capacity costs forecasted for the West Coast power market. Costs for the intermediate years were interpolated between the 1996 and 2004 values. Costs were assumed to remain constant after 2004. Hydrosystem impacts were calculated using values corresponding to the year the strategies could be fully implemented. Prior to that date, hydrosystem impacts were assumed to be similar to under current operations. The regional power costs presented in Tables 8 and 9 identify the 1996 and 2004 system costs as they would occur if the strategies were fully operational. The annual equivalent costs associated with the strategies, taking into account the differences in implementation dates, are also presented.[14]

Power Costs Associated with the Drawdown Alternatives

The final SOR incorporated four alternatives which focused primarily on drawdown of the Lower Snake projects. These included a seasonal, four and one-half month natural river drawdown of all four pools, a permanent, year-round natural river drawdown at all four pools, a four and one-half month drawdown to near spillway-crest levels at all four pools, and a four and one-half month spillway crest drawdown of the Lower Granite pool only. Each of the four alternatives also included drawdown of the John Day reservoir to minimum operating pool. The hydropower impacts associated with the drawdown alternatives are also presented in Table 8.

The power cost impacts associated with these alternatives are primarily related to lost generation during the drawdown period (including evacuation and refill). Generation at the Lower Snake projects is permanently lost under the twelve month drawdown option. Under the seasonal natural river alternative, generation at the projects is no longer possible when elevations drop fifty feet below normal operating pools (a drawdown of approximately one hundred feet is required to reach natural river levels). Although power generation losses under the seasonal drawdown are approximately 85 percent of losses under the permanent drawdown,

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14 / A more detailed presentation of the regional power costs associated with selected SOR alternatives is presented in Attachment C2.

the average annual equivalent power costs associated with the seasonal drawdown are only about one-third of those for the permanent drawdown. This is due, in part, to the significantly longer implementation period required for the seasonal drawdown (15 years compared to 5 years) and to the fact that generation losses under the seasonal drawdown do not have to be replaced during the more expensive winter period.

Table C-8
Regional Power Costs for Selected Drawdown Alternatives
(Measured in $1996, $1,000,000)

Drawdown Alternative	Annual Energy Production (aMW)	Average Annual Costs With Implementation		Equivalent Annual Cost
		1996	2004	
Current Operations	16,464	$1,146	$1,657	$1,465
Permanent Natural River	15,826	$1,141	$1,720	$1,491
Seasonal Natural River	15,943	$1,109	$1,653	$1,397
Seasonal Spillway Crest	16,494	$1,061	$1,558	$1,374
Lower Granite Only	16,682	$1,044	$1,528	$1,364
Changes Measured from Current Operations				
Permanent Natural River	(638)	($4)	($63)	$25
Seasonal Natural River	(521)	($36)	($4)	($69)
Seasonal Spillway Crest	30	($85)	($99)	($92)
Lower Granite Only	218	($102)	($129)	($102)

Source: *System Operation Review, FEIS, Appendix I, Power; System Operation Review, FEIS, Appendix O, Economic and Social Impact*, various tables.

Power Costs Associated with the Mixed Strategies

The mixed strategy options in the final SOR include the preferred alternative and a set of three options known collectively as the settlement discussion alternatives. Under the preferred alternative (SOS PA) flow targets are established at both Lower Granite and McNary dams. Spring and summer spill requirements are set at the Lower Snake and Lower Columbia projects to achieve 80% fish passage efficiencies. The Lower Snake projects are drawn down to minimum operating pools during spring and summer while the John Day reservoir is

operated at minimum pool year-round. The SOR preferred alternative is consistent with the operational requirements included in the NMFS Biological Opinion.

The settlement discussion alternatives (SOS 9) incorporated operating strategies suggested by the regional Tribes and fisheries management agencies. Alternative 9a, the Detailed Fishery Operating Plan (DFOP) included flow targets at Lower Granite and The Dalles, spill requirements at the Lower Snake and Lower Columbia projects, a spring/summer spillway crest drawdown of the Lower Snake projects, and a spring/summer drawdown of John Day to minimum operating pool. SOR alternative 9b, known as Adaptive Management, included flow targets at Lower Granite and McNary, spill requirements at the Lower Snake and Columbia projects, a spring/summer drawdown of the Lower Snake projects to minimum operating pool, and a spring/summer drawdown of John Day to minimum irrigation pool. Alternative 9c, known as the Idaho Plan, included a spring drawdown of the Lower Snake projects to spillway crest level, flow targets at McNary and Lower Granite dams, and a spring/summer drawdown of John Day to minimum irrigation pool.

Although the SOR preferred alternative is the only mixed operations strategy incorporated into the *Salmon Decision Analysis*, a comparison of the power costs related to the settlement options provides some insight as to the hydropower trade-offs associated with alternative flow-spill-drawdown regimes. All of the mixed strategies require significant amounts of water to be stored in fall and winter to meet spring and summer flow targets and spill requirements. As a result, replacement energy must be purchased during the fall and winter period when West Coast energy and capacity market prices are at their highest. The hydropower costs also reflect the lost generation caused by reservoir drawdowns at John Day and the Lower Snake projects. Average annual hydropower losses associated with the mixed strategy options are shown in Table 9. The average annual equivalent costs associated with these losses are also presented.

The detailed fishery operating plan (DFOP) resulted in the most significant reduction in hydropower generation of any of the alternatives examined in the SOR, including the permanent natural river drawdown. The loss of 788 average megawatts (aMW) annually relative to the preferred alternative results from the high levels of flow augmentation and spill required in the operations plan, along with the seasonal spillway crest drawdown of the four Lower Snake reservoirs. The Idaho Plan, with a similar combination of hydrosystem operations, has lower associated losses because of modified flow targets and a shorter duration drawdown relative to DFOP. The Adaptive Management strategy incorporates reservoir drawdowns to minimum operating pool and more significant Lower Snake and Columbia flow targets and spill requirements relative to the preferred alternative. Losses in hydropower generation under this alternative are less than under DFOP; a reduction of 304 aMW annually.

The mixed strategy alternatives that include spillway crest drawdowns of the Lower Snake reservoir (DFOP and the Idaho Plan) would require ten years for project modifications before

they could be fully implemented. The remaining two alternatives (the Preferred Alternative and the Adaptive Management strategy) were assumed to be implemented in the third year and first year of the planning period, respectively. Therefore, the average annual equivalent costs related to hydropower losses are greater for the alternatives without the spillway crest drawdown even though actual generation losses would likely be greater.

Table C-9
Regional Power Costs for Selected Drawdown Alternatives
(Measured in $1996, $1,000,000)

Mixed Strategy Alternative	Annual Energy Production (aMW)	Average Annual Costs With Implementation		Equivalent Annual Cost
		1996	2004	
Current Operations	16,464	$1,146	$1,657	$1,465
DFOP	15,676	$1,292	$1,853	$1,513
Adaptive Management	16,160	$1,218	$1,743	$1,571
Idaho Plan	16,042	$1,174	$1,710	$1,445
Changes Measured from Current Operations				
DFOP	(788)	$146	$196	$48
Adaptive Management	(304)	$72	$86	$106
Idaho Plan	(422)	$28	$53	($20)

Source: *System Operation Review, FEIS, Appendix I, Power; System Operation Review, FEIS, Appendix O, Economic and Social Impact*, various tables.

Costs Related to Energy and Capacity Production

The hydropower costs associated with the drawdown and mixed strategy alternatives are comprised of changes in both energy and capacity costs. In all cases, energy costs account for the most significant share of power system impacts. However, there is an important difference in capacity costs between alternatives.[15] Operating strategies that include reservoir drawdowns below minimum operating pool have a relatively larger portion of cost impacts

15 / Capacity impacts are related almost exclusively to changes in the ability of the hydropower system to produce sustained capacity.

related to capacity losses. This results from the significant reductions in reservoir elevations and/or loss of project generation, as in the permanent natural river drawdown. Capacity losses also result when restrictions are placed on the ability to draft reservoirs to meet power needs. This occurs when water must be held in reservoirs to meet flow augmentation requirements. Expected changes in energy and capacity costs related to the drawdown and mixed strategy alternatives are shown in Table 10. The capacity costs reflect the incremental changes in market capacity purchases relative to the SOR base case alternative. These costs are in addition to the capacity changes obtained through the new resource acquisitions to meet regional energy loads. As discussed in an earlier section, the new resource costs are incorporated into the estimated changes in system power costs related to changes in energy production.

Table C-10
Hydropower Costs Related to Energy and Capacity Production
(Measured as changes from the SOR Preferred Alternative, $1996, $1,000,000)

Alternative	Annual Energy Production	Average Annual Equivalent Costs		
		Energy	Capacity [a]	Total [b]
	(aMW)			
Drawdown Options				
Permanent Natural River	(638)	($22)	$55	$33
Seasonal Natural River	(521)	($91)	$17	($74)
Seasonal Spillway-Crest	30	($116)	$15	($101)
Lower Granite Only	218	($128)	$14	($114)
Mixed Strategy Options				
DFOP	(788)	$36	$16	$52
Adaptive Management	(304)	$118	$3	$121
Idaho Plan	(422)	$32	$10	$42

a/ Incremental market capacity purchases relative to SOS 2c.

b/ Total power costs reflect gross system replacement costs before accounting for accounting for net reductions in power demand as a result of expected changes in power rates.

Source: *System Operation Review, FEIS, Appendix I, Power; System Operation Review, FEIS, Appendix O, Economic and Social Impact*, various tables.

Reservoir Recreation

The Columbia-Snake River basin provides the region with a wide variety of water-based recreation activities. The streams and tributaries in the upper reaches and lower segments of the basin provide for river-based opportunities such as fishing, kayaking, and rafting while the flat water reservoirs of the system furnish a separate variety of fishing and boating experiences. The basin also provides for land-based recreation activities that are enhanced by the water resource setting, including picnicking, camping, and sightseeing.

The recreation analysis incorporated into the *Salmon Decision Analysis* is focused on the expected changes in reservoir activity that would result with implementation of the alternative Lower Snake recovery strategies. The analysis also includes the impacts of changing system operations on the free-flowing river reaches located immediately below Libby Dam on the Kootenai River and Dworshak Dam on the Clearwater River. Both of these areas have significant levels of recreation that would be affected by changing the operations of the adjacent reservoir.

Visitation to the various reservoir recreation sites located throughout the Columbia-Snake river basin is expected to average just under 18 million days annually based on current system operations. Lake Bonneville at Bonneville Dam accounts for the greatest number of annual visits (18%), followed by Lake Wallula at McNary Dam (15%), Lake Umatilla at John Day Dam (14%), Lower Granite Lake at Lower Granite Dam (9%), and Lake Roosevelt at Grand Coulee Dam (9%). The primary reservoir recreation season occurs between late spring and early fall. Average annual recreations visits expected under current system operations are shown in Table 11.[16]

Primary recreation activities at the reservoirs typically include sightseeing, fishing, boating, picnicking, and camping. Although reservoir water levels and river flows are important factors affecting overall recreation levels, the most important consideration is weather. Cool summers typically result in lower levels of recreation activity than warmer summers. Within a given recreation season, over fifty percent of visits occur between June and August, highlighting the importance of warm, dry weather to participation in water-based recreation activities.

The measurement of recreation impacts for the Salmon Decision Analysis relies exclusively on the comprehensive recreation analysis conducted for the SOR. Estimated changes in recreation visits and recreation values from the SOR are used to calculate the effects that alternative

16 / A more detailed presentation of recreation visits and recreation values for various locations throughout the basin are provided in Attachment C3.

pathway strategies may have on Columbia-Snake river basin recreation. Recreation impacts for the pathway analysis are measured as changes from current system operations. The SOR preferred alternative was modified to exclude the John Day MOP operation in order to represent expected recreation impacts under current system operations.

Table C-11
Expected Average Annual Recreation Days Under Current System Operations

Recreation Reservoir	Visits	Primary Activity
Upper Columbia Projects	**5,185,078**	
Hungry Horse Dam & Lake	133,530	Camping, fishing, boating
Libby Dam/Lake Koocanusa	601,640	Fishing, swimming picnicking
Kootenai River	24,960	Fishing
Albeni Falls Dam/Lake Pend Orielle	1,243,190	Camping, boating, sightseeing
Columbia River, Canada	39,131	Picnicking, sightseeing
Grand Coulee Dam/Lake Roosevelt	1,612,827	Camping, sightseeing, fishing
Chief Joseph Dam/Rufus Woods Lake	47,900	Sightseeing, fishing
Mid Columbia PUDs	1,481,900	Sightseeing, fishing
Lower Snake Projects	**2,918,534**	
Snake River Hells Canyon	43,500	Whitewater boating, fishing
Dworshak Dam & Lake	149,645	Sightseeing, boating, fishing
Clearwater River	151,296	Fishing
Lower Granite Lake & Dam	1,673,460	Picnicking, boating, swimming
Little Goose Dam/Lake Bryan	242,655	Picnicking, boating, swimming
Lower Monumental Dam/Lake West	138,766	Picnicking, boating, swimming
Ice Harbor Dam/Lake Sacajawea	519,212	Picnicking, boating, swimming
Lower Columbia Projects	**9,878,789**	
McNary Dam/Lake Wallula	2,747,500	Sightseeing, fishing, boating
John Day/Lake Umatilla	2,555,359	Sightseeing, fishing, boating
The Dalles Dam/Lake Celilo	1,411,300	Sightseeing, fishing, boating
Bonneville Dam & Lake	3,164,300	Sightseeing, fishing, boating
Total for all Sites	**17,982,401**	

Source: *System Operation Review, Final EIS, Appendix J, Recreation.*

The Effects of Changing Operations on Reservoir Recreation

The SOR recreation analysis focused on fourteen federal projects located throughout the Columbia-Snake River basin. These included both storage and run-of-the river projects.[17] Changing system operations would affect recreation opportunities differently at these project types. Storage reservoirs have typically been operated to store water in spring and summer to provide for releases later in the fall and winter when additional flows are required for power generation. These reservoirs provide the greatest opportunities for recreation when they are at or near full pool. This has typically occurred during spring and summer, coinciding with the prime recreation season. Recreation at storage projects is affected primarily by operations that delay reservoir refill until late in the summer, or cause the reservoir to be drawn down earlier in the fall.

Historically, run-of-the-river projects do not experience large fluctuations in pool levels, making them suitable for recreation year-round. Recreation activity at these projects, however, can be affected by the timing and velocity of flows. High-velocity flows create turbulence, causing safety hazards for boaters and swimmers. Operation strategies that caused significant flow increases through run-of-the river projects will have adverse impacts on recreation activity.

Several of the system operation alternatives evaluated in the Salmon Decision Analysis also include drawdowns of the Lower Snake and John Day projects, resulting in water elevations levels that are well below levels considered suitable for recreation.

Measuring the Value of Reservoir Recreation

Changes in reservoir water levels or water velocities associated with alternative operating strategies are expected to affect the level of recreation activity at the various reservoir sites. In order to compare the trade-offs between changes in recreation activity and the other water-based resource activities (hydropower, navigation, and irrigation), the economic values associated with changing levels of reservoir recreation were measured. A comprehensive analytical study based on an extensive survey and data collection effort was conducted to determine the recreation values associated with the project reservoirs.[18]

17/ The federal storage projects include Hungry Horse Dam on the Flathead River, Libby Dam on the Kootenai River, Albeni Falls Dam on the Pend Orielle River, Grand Coulee Dam on the upper Columbia River, and Dworshak Dam on the Clearwater River.

18/ The recreation survey and modeling effort are described in detail in *the System Operation Review, Final EIS, Appendix J, Recreation*, November 1995.

Reservoir recreation values take into account the characteristics of the recreation site, the variety of recreation opportunities available at the site, reservoir water levels, and the preferences that individuals have for the range of recreation opportunities available to them. Total recreation value is determined by the number of recreation trips an individual takes to a site and the value that the individual places on the recreation experience.

Recreation values have most typically been measured on the basis of the travel costs necessary to participate in the activity. The value that an individual connects with a recreation experience is at least as great as the level of expenditures required to participate in the experience (e.g. costs associated with food, lodging, transportation, entrance fees, equipment, etc.). In general, the farther an individual has to travel to a recreation site, the higher will be the associated travel cost. Individual preferences for a particular site will vary; some recreators are willing to incur more costs than others to participate in the same recreation activity. Modeling these differences in 'willingness-to-pay' across individuals allows an aggregate relationship to be estimated between the number of visits to a recreation site and the value associated with those visits. This methodology, based on visitor travel costs, was incorporated into the recreation analysis conducted for the SOR.

The estimated relationship between recreation visits and recreation values was based on actual trip behavior as reported by respondents to the recreation survey. In addition to travel cost information, the survey also included computer-enhanced photographs of alternative water levels at selected reservoir sites. Survey respondents were asked to indicate whether and how their decision to visit a reservoir would be affected by changes in water levels. This information was used to determine the change in recreation days at specific reservoirs under the alternative operating strategies. The relationship between recreation visits and willingness to pay was then utilized to determine the overall change in the reservoir recreation values associated with alternative operating strategies.

Recreation values were not estimated for three of the federal projects located on the Lower Columbia River (Bonneville, The Dalles, & McNary dams) and Chief Joseph Dam on the Upper Columbia River. The screening analyses conducted during the earlier phases of the SOR indicated that recreation impacts under all operations would be minimal at these projects. The expected changes in recreation values for the Hells Canyon stretch of the Lower Snake River and the portion of the Upper Columbia River located in Canada (Grand Coulee Dam to Hugh Keenlyside Dam) were not estimated due to insufficient information. Results for the remaining project sites are presented in the following section.

Expected Changes in Reservoir Recreation

The estimated changes in recreation visits for selected operating strategies are shown in Table 12. Changes are measured relative to current system operations. System-wide, changes in reservoir recreation are most significant under the permanent natural river drawdown and

under DFOP, a mixed strategy that includes a spillway crest drawdown at the Lower Snake projects along with flow augmentation and project spill requirements. Recreation under both alternatives is expected to decline by approximately 2 million visits region-wide, a decrease of about 11 percent.

Table C-12
Estimated Change in Recreation Visits for Selected Alternatives
(Change Measured from Current Operations)

Reservoir Site	Perm. Nat. River DD	Seas. Nat. River DD	Spillway Crest DD	Lwr Grnt Only DD
Upper Columbia River	**34,323**	**34,323**	**34,325**	**34,325**
Lower Snake River	**(1,611,758)**	**(1,360,927)**	**(696,045)**	**(399,521)**
Dworshak	77,287	64,066	49,209	49,209
Clearwater River	(9,707)	(24,585)	(17,391)	(17,391)
Lower Granite	(1,021,170)	(814,170)	(423,436)	(423,436)
Little Goose	(171,512)	(149,984)	(78,253)	(2,253)
Lower Monumental	(94,714)	(81,189)	(42,274)	(1,168)
Ice Harbor	(391,942)	(355,065)	(183,900)	(4,482)
Lower Columbia River	**(434,431)**	**(434,431)**	**(434,431)**	**(434,431)**
John Day	(434,431)	(434,431)	(434,431)	(434,431)
Region Total	**(2,011,866)**	**(1,761,036)**	**(1,096,151)**	**(799,627)**
Reservoir Site	**DFOP**	**Adaptive Management**	**Idaho Plan**	
Upper Columbia River	**(704,760)**	**(224,606)**	**(51,636)**	
Lower Snake River	**(840,240)**	**(126,908)**	**(290,944)**	
Dworshak	30,716	(16,443)	33,447	
Clearwater River	(15,04)9	(16,025)	(7,969)	
Lower Granite	(498,122)	(55,141)	(187,982)	
Little Goose	(90,746)	(9,580)	(39,338)	
Lower Monumental	(49,410)	(5,345)	(19,495)	
Ice Harbor	(217,629)	(34,374)	(69,607)	
Lower Columbia River	**(451,540)**	**0**	**(487,106)**	
John Day	(451,540)	0	(487,106)	
Region Total	**(1,996,540)**	**(351,514)**	**(726,414)**	

Source: Columbia River *System Operation Review, Final EIS, Appendix J, Recreation.*

The economic values associated with reservoir recreation vary across the operating alternatives, based on the expected change in recreation visits. Changes in average annual recreation values are presented in Table 13.

Table C-13
Change in Recreation Values for Selected Alternatives
(Values in $1996, $1,000,000; Change Measured from Current Operations)

SOR Alternative	Upper Columbia	Lower Snake	Lower Columbia	Region Total [a]
Drawdown Alternatives				
Permanent Natural River	$4.6	($63.2)	$0	($58.6)
Seasonal Natural River	$5.0	($28.3)	$0	($23.3)
Seasonal Spillway-Crest	$4.9	($22.2)	$0	($17.4)
Lower Granite Only	$4.6	($18.3)	$0	($13.6)
Mixed Strategies				
DFOP	($24.7)	($27.1)	$0	($51.8)
Adaptive Management	($21.8)	($8.3)	$0	($30.1)
Idaho Plan	($0.6)	($7.6)	$0	($8.2)

a/ Numbers may not add up due to rounding.

Source: Columbia River *System Operation Review, Final EIS, Appendix 0, Economic and Social Impact.* Calculated from values presented in Table 4-49.

Recreation Impacts Under the Drawdown Scenarios

A spillway crest drawdown at Lower Granite would drop summertime elevations by 33 feet while the natural river drawdown would lower the pool elevation by more than 100. Similar declines in reservoir elevations would occur at the other three Lower Snake projects.

The most significant recreation impacts at the Lower Snake projects occur with the permanent natural river drawdown. Recreation visits at the four projects are expected to decline by 1.6 million annually, accounting for 55 percent of the 2.9 million annual visits expected current operations. Recreation values region-wide are expected to decline by $59 million annually under permanent drawdown. The largest share of losses would be associated with the change in operations at Lower Granite reservoir.

The seasonal year natural river drawdown also leads to significant declines in recreation at the Lower Snake projects, since the drawdown occurs during the primary recreation season. Under this drawdown scenario, visits decline by nearly 1.4 million. Region-wide recreation values are expected to decline by $23 million. The spillway crest drawdowns (four-pool and one-pool) lead to more moderate declines in recreation visits at the Lower Snake projects, 696,000 and 400,000, respectively. Differences in recreation visits under the drawdown alternatives are linked primarily to the length of the drawdown rather than depth of the drawdown. Most of the boat launches and swimming beaches at the reservoirs become inaccessible below minimum operating levels (3 to 5 feet below full pools).

Recreation Impacts Under the Mixed Strategy Scenarios

The recreation impacts associated with the mixed strategy scenarios are, of course, dependent on the set of river management options included in the alternative. The DFOP alternative results in a significant decline in reservoir recreation, a reduction of nearly two million visits. The alternative combined a four and one-half month spillway-crest drawdown at the Lower Snake projects with significant flow augmentation requirements on the Columbia River and a four month drawdown of John Day to MOP. Consequently, losses were spread throughout the system: 35 percent of the decline in visits would occur on the Upper Columbia, 42 percent on the Lower Snake, and 23 percent on the Lower Columbia.

The Adaptive Management alternative includes considerable flow augmentation requirements on the Columbia and Snake rivers, but does not include reservoir drawdowns. Recreation impacts under this alternative are significantly less than those measured for the other mixed strategy options. The Idaho Plan combines more modest flow augmentation requirements with a two month spillway crest drawdown on the Lower Snake and a four month drawdown of John Day to MOP. Estimated recreation impacts are significantly less than those measured for the DFOP alternative, a decline of slightly less than 725,000 visits.

Other Recreation Issues

Several factors could affect the overall magnitude of the economic impacts associated with reservoir recreation. These issues are addressed qualitatively in the sections below; the potential affect on changes in recreation values for alternative operating strategies have not been measured.

Potential Mitigation

In some cases, the adverse affects of changes in river operations on reservoir recreation could be avoided or minimized through mitigation efforts. The effectiveness of potential mitigation strategies for the alternative operational changes would depend on the severity of the impacts

to recreational facilities and site suitability. Four general categories of mitigation have been identified: 1) providing the public with up-to-date information on reservoir conditions and available recreation opportunities; 2) revising short-term reservoir operations to minimize recreation impacts; 3) modifying recreation facilities to allow for a greater range of accessibility during fluctuating reservoir operations; and 4) providing comparable off-site recreation opportunities where on-site mitigation cannot be accomplished (as in the case of significant reservoir drawdowns).

Benefits of Restored River Segment

The most significant losses in recreation values were found to occur with the permanent natural river drawdown of the four Lower Snake projects. Under this alternative, a new river bypass would be created around the project facilities, restoring the natural river segment along the Lower Snake River. The estimated recreation impacts for this alternative do not take into account the new recreation opportunities that would be made available with the restoration of natural river conditions. The economic values associated with the natural river recreation would likely compensate for a portion of the reservoir losses under the permanent drawdown.

Next Best Alternative

Recreation impacts developed for the SOR reflect the values that individuals place on the variety of reservoir recreation experiences provided by the Columbia-Snake project facilities. Operational changes which result in a decline in the availability or quality of these recreation experiences lead to a decline in the values associated with the project reservoirs. While these values are lost to the Columbia-Snake River system, the entire value may not be lost to the individual or to the region. It is likely that with reservoir recreation unavailable, individuals would seek out a "next best" recreation alternative. Taking into account these non-reservoir alternatives was beyond the scope of the SOR analysis.

Navigation

The Columbia-Snake River waterway furnishes an important commercial navigation channel, providing access from the region's interior basins to the Pacific ocean. The authorized commercial shipping channel on the Columbia system extends from its ocean entrance to the confluence of the Snake and Clearwater rivers at Lewiston, Idaho, a navigable stretch of 465 miles. A deep draft channel, suitable for ocean-going vessels, is maintained over the first 100 mile segment of the river (up to the ports at Portland, Oregon and Vancouver, Washington). The remaining channel accommodates shallow-draft traffic including tugs, barges, and recreational boats.

Waterway navigation along the Columbia and Snake Rivers is used primarily to move agricultural commodities and wood products from the inland locations where they are produced to the deepwater shipping ports on the lower river for export overseas. Six barge companies currently operate transportation services along the river system, furnishing approximately forty tugs and 175 barges. Fifty-four port facilities are located along the river. Two-thirds of these are located in the McNary and Lower Snake pools. Grain commodities, primarily wheat and corn, account for seventy-five percent of total movements along the river. The remainder of the commodities shipped downstream include primarily logs, wood chips, and soda ash.

The Effects of Changing Hydrosystem Operations

Inland navigation requires shipping channels to be maintained at sufficient depths so that travel is not impaired. In the deep draft segment of the Lower Columbia River, sufficient navigation depths are generally provided by natural flows. In the upper portions of the river however, shallow draft navigation channels must be maintained by managing water releases to insure adequate reservoir levels. Changes in system operations which significantly lower pool elevations in the navigable reservoirs would restrict commercial water transportation.

Changing system operations can affect commercial navigation along three distinct segments of the Columbia-Snake river system: impacts can occur to deep-draft navigation on the Lower Columbia River; shallow-draft navigation can be affected, particularly in the Lower Snake pools; and pool fluctuations can impact authorized log rafting operations on Dworshak reservoir.

The navigation analysis completed for the *System Operation Review* is used to evaluate navigation-related impacts for the *Salmon Decision Analysis*. The SOR preferred alternative is considered to be representative of navigation impacts for current system operations, defined as the base case for the decision analysis. One of the key distinctions between the SOR preferred alternative and current operations is the inclusion of a John Day drawdown to MOP in the SOR strategy. Because no economic impacts to navigation were measured for the John

Day drawdown, the preferred alternative is considered representative of current operations in the present study.

Deep Draft Navigation

As part of the SOR, an analysis was completed to determine whether ocean-going vessels utilizing the forty-foot navigation channel between Vancouver, Washington and the mouth of the Columbia River would incur travel delays or other problems during refill of the Snake River reservoirs after drawdown. The refill requirements would reduce Snake River inflows into the Columbia below present levels. The lower inflows would alter river stages along the Lower Columbia River, potentially affecting deep draft navigation for in-bound and out-bound ocean vessels.

The results of the analysis indicated that the impacts of the refill operations on river stages at critical locations along the Lower Columbia River would be relatively small. It was concluded by the Navigation Work Group that the SOR alternatives would have no impact on deep draft navigation. Consequently, no economic costs were measured for this navigation component.

Shallow Draft Navigation

Alternative river operation strategies would affect shallow draft transportation on the Columbia-Snake system by limiting and/or restricting barge navigation along specific river reaches during periods of drawdown. To compensate for the seasonal (or permanent) closure of the navigation waterway, alternative transportation methods would have to be utilized by inland shippers. Two general transportation adjustments would occur as a result of restrictions to barge navigation: i) the restrictions may cause shifts from barge movements to other transportation modes or modal combinations (e.g., shifts from truck-barge to truck-rail); or ii) the Lower Snake drawdown operations may result in commodities being transported to alternative river locations before being placed on barges; (e.g., shifts from river ports in the Lewiston area to river ports in the Tri-Cities area).[19] Either of these adjustments is likely to require increased product storage and handling in order to transfer and hold commodities before delivery along alternative transportation nodes.

Grain shipped to export elevators on the Lower Columbia River originates in Oregon, Washington, Idaho, Montana, and North Dakota. Nearly all of the grain shipped from

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19 / Only a small portion of grain shipments are trucked directly to the export terminals. These shipments generally originate from nearby locations in Washington and Oregon since costs prohibit trucking over long distances. Therefore, direct trucking was not considered a likely alternative for grain movements that currently utilize the Snake River navigation channel.

Montana and North Dakota is transported by rail directly to the export terminals whereas shipments from Oregon and Washington utilize primarily barge transportation. Grain movements from Idaho are equally split between barge and rail. Washington and Idaho shipments account for nearly all of the movements from the Lower Snake pools. During a drawdown period it is expected that a portion of the Washington grain normally transported from ports on the Lower Snake would be trucked downstream to the McNary pool and loaded on barges. The remainder of grain from Washington would be transported by rail, along with all of the shipments from North Dakota and Montana that would have been shipped from the Lower Snake pools during the drawdown period. Idaho grain that would have been shipped from the Lower Snake ports would be transferred to rail.

Dworshak Log Rafting Operations

As one of its federally authorized uses, Dworshak Reservoir is utilized by the area wood products industry for commercial log transportation. Timber logged from the North Fork drainage of the Clearwater River is hauled to log dumps at the upper end of the pool, where it is assembled into rafts and transported across the reservoir. The logs are then loaded onto trucks and transported to mills for further processing. System operations which lower Dworshak Reservoir below 1,585 feet (approximately 15 feet below full pool) would prohibit access to the log dumps, thereby preventing the log transport activities.

Measuring Economic Costs

Alternative hydrosystem operation strategies would affect cargo shipments on the Columbia-Snake River system by limiting and/or restricting barge navigation along specific river reaches during periods of reservoir drawdown. The barge restrictions would, in turn, lead to increases in the costs of transporting goods from their point of origin to their final destination. Increased transportation costs result from two general adjustments that would occur as a result of restrictions to barge navigation: i) barge movements may shift to other transportation modes or modal combinations, or ii) commodities may be transported to alternative river locations before being loaded on barges. Increased storage and handling costs would also be likely to result from the shifts in transportation activity.

The direct economic impacts related to navigation on the Columbia-Snake River system were measured as the net change in transportation costs for grain and non-grain commodities. Expected costs were estimated for shallow draft navigation and for Dworshak Reservoir log rafting operations. Expected changes in average annual transportation costs are presented in Table 14 for selected operations strategies.

The severity of the navigation impacts are directly correlated with the number of months the locks are inaccessible to barge traffic. Impacts to navigation are most significant under the

permanent natural river drawdown, where average annual equivalent costs are expected to increase by $33 million. The seasonal natural river drawdown, with locks inaccessible for seven months out of the year, would lead to average annual increases in transportation costs of $24 million. Fifteen years would be required to complete project implementation, leading to an annual equivalent cost of $7.7 million. The four-pool spillway-crest drawdown would shut down the navigation locks for five months, lessening the average annual transportation costs of this alternative relative to the seasonal natural river drawdown. However, because of the spillway crest drawdown could be implemented in ten years, the average annual equivalent costs associated with this alternative are slightly higher than for the seasonal natural river drawdown.

Table C-14
Navigation Costs for Alternative System Operations, *$1,000,000*
$1996 average annual equivalents measured as changes from current operations[a]

Drawdown Alternative	Months Locks Inaccessible	Average Annual Costs	Years to Implement	Equivalent Annual Cost
Permanent Natural River	12	$48.3	5	$33.2
Seasonal Natural River	7	$24.1	15	$7.7
Seasonal Spillway Crest	5	$18.6	10	$8.7
Lower Granite Only	5	$2.8	5	$1.9

a/ Current operations include minor costs related to Dworshak Reservoir transportation only. No impacts to shallow draft navigation occur under current operations.

Source: Columbia River System Operation Review, *Appendix O, Economic and Social Impact.*

Other Navigation Issues

Closure of the Snake River ports during drawdown will result in a portion of the grain normally shipped from the reservoirs to be trucked further downstream to ports on the Columbia River, particularly for grain shipments originating in Washington state. The increased truck hauling will reduce highway pavement life, leading to increased pavement damage. The increased damage will require greater annual expenditures for highway maintenance. It has been estimated by the state of Washington that maintenance costs could increase by as much as $1.5 million annually for the seasonal drawdowns and by $4 million

annually with a permanent drawdown.[20] These impacts would be offset to some degree by the expected decline in truck hauling in Idaho and Montana, where closure of the Snake River ports would cause a portion of commodity movements to shift from truck-barge routes to rail routes.

Irrigation and Municipal/Industrial Water Supply

Regional water demands for irrigation and municipal/industrial water supplies are met primarily through diversions of surface water resources; groundwater accounts for less than twenty-five percent of regional water use. Approximately six percent of average annual water flows in the Columbia-Snake river system are diverted for agriculture while less than two percent of flows are used to meet municipal and industrial water demands. Agricultural diversions are used to irrigate over seven million acres of Pacific Northwest cropland, comprising nearly one-half of the region's harvested land base. Areas of significant irrigation include the Yakima Valley and the Columbia Basin in central Washington, the Upper Snake River basin in southern Idaho, and the Deschutes basin in central Oregon. Direct diversions for irrigation water supplies have been developed in the Ice Harbor, McNary, and John Day pools along the Lower Snake and Columbia Rivers. Water supplies for the Columbia Basin project in central Washington are delivered from Banks Lake, an off-stream equalizing reservoir, which pumps irrigation water directly from the Grand Coulee pool.

Diversions for municipal and industrial purposes are used for a wide range of applications, including domestic, commercial and industrial uses, public water supplies, recreation, wildlife habitat, mining, and livestock watering. Surface water withdrawals for these non-agricultural uses occur on numerous streams and tributaries throughout the Columbia-Snake River basin. Direct diversions also occur at many of the federal reservoirs, with most withdrawals concentrated in the Lower Granite and McNary pools.

Measuring Economic Costs

The direct economic impacts for water supply were estimated for those individuals and activities that pump water directly from reservoir pools on the Lower Snake River. Impacts were estimated separately for pumping related to irrigation for commercial agriculture and pumping related to other water supply needs, including municipal, industrial, recreation, and

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20 Lenzi, J.C. and K. L. Casavant, "Prospective Estimates for Road Impacts in Eastern Washington from a Drawdown of the Lower Snake River," paper presented at the 1996 Pacific Northwest Regional Economic Conference.

wildlife uses. Six reservoirs currently utilized for irrigation and water supply pumping would be affected by changes in river system operations to enhance Lower Snake juvenile fish survival, including:

- Grand Coulee reservoir via Banks Lake *(irrigation pumping)*;
- John Day and Ice Harbor reservoirs *(irrigation pumping and municipal and industrial water supply pumping)*; and
- Lower Granite, Little Goose, and Lower Monumental reservoirs *(municipal and industrial water supply pumping)*.

Direct diversions for irrigation and municipal/industrial water uses also occur in the McNary pool on the Lower Columbia river. However, because McNary reservoir elevations would not likely be affected by any of the pathway alternatives currently being examined, pumping impacts in the pool were not included in the water supply evaluation. The *Salmon Decision Analysis* is focused primarily on operational changes at the Lower Snake reservoirs. Therefore, the discussion below focuses on water supply impacts at these four reservoirs. Earlier studies prepared for the System Operations Review are used as the basis for determining the expected changes in pumping costs for the pathway alternatives.

Irrigation Water Supply

Direct diversions for irrigation pumping occur in the Ice Harbor reservoir pool. Thirteen pumpers irrigating 37,000 acres operate from the Ice Harbor pool. Under several of the SOR alternatives, drawdown of the Ice Harbor pool would be significant enough to require modification of the existing pumping stations in order to maintain pumping throughout the irrigation season. Significant capital cost would be associated with the pump modifications necessary to maintain pumping at the lower pool elevations. In addition to the pump station modification costs, most irrigators would experience higher horse-power requirements and higher energy costs due to increased pumping lifts under a drawdown operation. As the level of the reservoir is lowered under the SOR alternatives, energy requirements to pump the water out of the pool and into irrigation delivery systems would increase. The change in energy requirements would, in turn, increase the pumping costs that must be paid by growers. Irrigators would also experience an increase in annual operations and maintenance costs as a result of the structural modifications. All of these costs combine to determine the annual increase in pumping costs that would be faced by regional irrigators.

Municipal/Industrial Water Supply

Pumping for municipal and industrial water supplies in one or more of the Lower Snake reservoir pools would be affected by the drawdown alternatives. Non-agricultural pumps at the Ice Harbor, Lower Granite, Little Goose, and Lower Monumental projects include a variety of municipal and industrial water users, state and federal recreation and wildlife areas, and city and county parks. As in the case of irrigation pumping, drawdown of these pools under some pathway alternatives would be significant enough to require modification of the existing pumping stations. It is expected that sixteen non-agricultural pumping stations would be affected in these four pools, nine of which are located at Lower Granite.

Summary of Water Supply Impacts

The expected increase in irrigation and municipal/industrial pumping costs for selected pathway alternatives are presented in Table 15. Costs are presented in terms of average annual equivalent values, which take into account the differences in implementation dates across the alternatives. Annual costs include the annualized investment cost as well as the expected increase in annual operations and maintenance costs and the expected increase in annual pumping costs. Modification costs for the water supply pumping stations are directly linked to the lowest reservoir elevation expected to occur during drawdown; the lower the elevation the greater the costs required to extend the stations. The most significant increase in water supply costs would be expected under the seasonal and permanent natural river drawdowns where reservoirs would be drafted one hundred feet below normal operating levels.[21]

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21 / In the SOR analysis nearly all of the increased pumping costs for the municipal/industrial water supply diverters were related to the pump station modifications required in the John Day pool. It was also estimated that 30 to 40 percent of the increased costs for irrigation diversions would occur in the John Day pool. The John Day costs are directly related to requirements to draft the reservoir to minimum operating pool, which is approximately 5 feet below the minimum irrigation pool. Increased pumping costs for diversions from Grand Coulee were found to be insignificant, generally less than $25,000. None of the alternatives lowered reservoir elevations to levels below the existing pumping stations. Therefore, Grand Coulee costs include only the expected increase in energy costs for pumping. Under the Lower Snake drawdown options (SOSs 5 and 6) elevations at Grand Coulee were unchanged from the SOR base case alternative (SOS 2c), resulting in no change in pumping costs for the Columbia Basin diverters.

Table C-15
Increased Water Supply Costs for the Lower Snake Reservoirs, *$1,000,000*
$1996 measured as changes from Current Operations

Drawdown Alternative	Capital Cost	Average Annual Equivalent Cost		
		Irrigation	Municipal/ Industrial	Total Water Supply
Permanent Natural River		$39.0	$0.7	$3.8
Seasonal Natural River		$39.0	$0.3	$1.7
Seasonal Spillway Crest		$21.8	$0.3	$1.4
Lower Granite Only		$3.0	$0.3	$0.3

Source: Columbia River *System Operation Review, Final EIS, Appendix F, Irrigation, Municipal and Industrial Water Supply.* Values presented in Tables A-1, A-2, and A-3.

Summary of Economic Impacts

A summary of the economic costs associated with selected drawdown and mixed strategies are presented in Table 16. Values are presented as average annual equivalents, which take into account the different implementation dates associated with the alternatives. The drawdown and mixed strategy alternatives include many of the operational changes and structural modifications that have been selected for further examination in the *Salmon Decision Analysis*. All of the costs, except hydropower, are related to impacts primarily at the Lower Snake reservoirs. Hydropower impacts for the selected alternatives also include costs generated by requirements that the John Day reservoir be operated at minimum operating pool. An analysis is currently underway to remove the effects of the John Day operation from the hydropower impacts related to Lower Snake drawdown and mixed strategy options. Results of this analysis should be available in Fall 1996.

Total economic costs are most significant for the SOR alternative described as the *Detailed Fish Operating Plan (DFOP)*. The mixed strategy combines a four month spillway-crest drawdown at the Lower Snake reservoirs with high spring and summer flow targets on both the Snake and Columbia Rivers. The strategy would require ten years for implementation, primarily due to the project modifications that would be required to accommodate the spillway-crest drawdown. The strategy's $166 million annual economic cost is distributed nearly equally across project construction, increased power costs, and lost recreation benefits. Under the DFOP strategy, significant amounts of water would be stored during fall and winter to meet the spring and summer flow requirements. As a result, replacement energy must be purchased during fall and winter when power market prices are generally at their highest. The high level of incremental power costs related to this alternative also reflects the reduction in power generation at the Lower Snake reservoirs during the drawdown period.

The permanent and seasonal natural river drawdowns are also estimated to result in significant economic costs to the region, with annual losses estimated at $124 and $130 million, respectively. The permanent drawdown would lead not only to significant increases in regional power costs but would also result in the greatest decline recreation values of all the pathway strategies examined in this analysis. Costs associated with the seasonal natural river drawdown are related primarily to project construction.

Table C-16
Summary of Economic Costs for Selected Alternatives, *$1,000,000*
$1996 Average annual equivalents measured as changes from Current Operations

Economic Costs	Perm. Nat. River DD	Seas. Nat. River DD	Seas. Splwy Crest DD	Lwr. Grnt. Only DD
Project Implementation	$36	$168	$57	$5
Power	$25	($69)	($92)	($102)
Recreation	$59	$23	$17	$14
Navigation	$33	$8	$9	$2
Water Supply [a]	—	—	—	—
Total Economic Costs	$153	$130	($9)	($81)
years to implement	*5*	*15*	*10*	*5*
	DFOP	**Adaptive Management**	**Idaho Plan**	
Project Implementation	$57	$0	$57	
Power	$48	$106	($20)	
Recreation	$52	$30	$8	
Navigation	$9	$0.2	$5	
Water Supply [a]	—	—	—	
Total Economic Costs	$166	$136	$50	
years to implement	*10*	*0*	*10*	

a/ Water supply impacts are included as mitigation costs in the cost estimates presented for project implementation.

Cost Effectiveness

A summary of the economic costs associated with alternative operations strategies for the Columbia-Snake system does not provide sufficient information to choose among alternatives. The impact of the alternatives on other river uses must also be considered, including any positive or adverse consequences to cultural resources, resident fish and wildlife, and water quality. In evaluating alternative strategies for the *Salmon Decision Analysis*, measures related to the biological outcomes for juvenile salmon survival and adult return rates would be the primary indicators for selecting among possible operating alternatives. Examining the trade-offs between economic costs and other desired outcomes is generally referred to as a cost-effectiveness comparison.

The cost-effectiveness of the operating strategies can be evaluated by ranking the alternatives in terms of their costs per unit of a desired physical outcome. For the SOR, a cost-effectiveness ranking was done by comparing the incremental change in economic costs with the incremental change in anadromous fish harvest for each of the study alternatives. In the case of the *Salmon Decision Analysis*, the cost-effectiveness ranking is based on the incremental economic costs associated with a percentage increase in juvenile survival rates.

Although a cost-effectiveness ranking of alternative strategies does not provide complete information to a decision-maker regarding the desirability of selected options, it does provide an important indicator of the least-cost pathways to achieve similar desired outcomes. Issues related to cost-effectiveness are discussed further in *Risk and Uncertainty* section of the main document.

Regional Economic Impacts

The direct economic impacts associated with the alternative pathway strategies are measured in terms of changes in the value of commodities and activities for selected river uses directly affected by the alternatives, including recreation, irrigation and water supply, navigation, and hydropower generation. The construction costs required to implement the alternatives are also an important component of the economic costs of alternative strategies.

Adjustments in river operations will affect the demand for local goods and services, causing the output levels in many related industries to change. Input requirements will be affected, as will the distribution of regional output to local and export markets. Labor requirements will change, increasing or decreasing the availability of regional jobs. Personal income will rise or fall depending on the job impacts. The regional trade balance will shift as the availability of local commodities is affected by changes in production levels. The most common indicators of changes in regional economic activity however, are adjustments in regional employment and earnings. Regional economic impacts for the pathway alternatives are based on studies developed for the SOR and SCS Phase I studies. Regional impacts were estimated using the input-output methodology, which measures the economic dependencies between businesses and industries in a regional economy. Average annual changes in employment and personal income were used as indicators of the regional economic impacts associated with the operating alternatives.

The direct economic impacts for the SOR and SCS alternatives were measured for activities occurring throughout the Pacific Northwest (Washington, Oregon, Idaho, and Montana). However, the actual incidence of the direct impacts would likely be distributed unevenly throughout various locations in the region. Consequently, it is likely that the regional economic impacts associated with the direct changes will occur in some parts of the Pacific Northwest, while not in others. To better reflect the dispersion of intra-regional impacts, eight multi-county subregions were identified to further evaluate regional economic impacts. The boundaries of the regions were determined, in part, by the expected incidence of the direct economic impacts. The eight subregions are defined below.

Puget Sound: Five (5) counties in northwestern Washington.

West Coast: Ten (10) counties extending from the central Washington coast southward to the central Oregon coast.

Portland: Five (5) counties in Oregon and Washington surrounding the Portland metropolitan area.

Mid Columbia: Eleven (11) counties in Oregon and Washington located along the mainstem of the Columbia River above Portland.

Upper Columbia:	Eight (8) counties in north central Washington, including counties along the upper reaches of the Columbia River.
Lower Snake:	Twelve (12) counties in southeastern Washington, central Idaho, and northeastern Oregon located along the Clearwater, Salmon, and Lower Snake Rivers.
Northeast:	Fifteen (15) counties in northeastern Washington, northern Idaho, and western Montana.
Southern Idaho:	Thirty-three (33) counties, including all of southern Idaho, along the upper Snake River, and a portion of southeastern Oregon.

The regional effects of the direct economic impacts were also evaluated to determine the state-level changes likely to occur under the various alternatives. To measure these impacts, individual input-output models were developed for Oregon, Washington, Idaho, and Montana.

Measures of Regional Economic Change

Regional economic impacts were measured differently for each of the river resources potentially affected by changes in hydrosystem operations. The direct economic impacts estimated for power, recreation, navigation, water supply, and project construction provide the basis for the regional impacts. In the case of power, it is assumed that an increase in the regional power bill would result in a direct decline in household income available to Pacific Northwest ratepayers for the purchase other goods and services. The reduction in the purchase of these other commodities would lower business sales, leading to a loss of regional employment and income.

The estimated changes in recreation values for the direct economic analysis were derived, in part, from the expected changes in the number of recreation visitors to reservoirs along the Columbia and Snake Rivers. The regional economic impacts associated with recreation would be caused by the changes in trip-related expenditures by visitors on-site and en-route to their recreation destinations. The decline in recreation sales by local area businesses leads to a loss of regional employment and income.

Expected changes in irrigation pumping costs and transportation costs for commodity shipments would be likely to generate similar regional economic impacts. In both cases, the increased costs would be paid for primarily by agricultural growers, leading to a decline in the net farm income earned by farming operations.[22] With less business income available farm

22/ A similar analysis was done for shippers of nonagricultural commodities, including logs, wood chips, and petroleum. In these cases the income losses were assumed to accrue to the commodity manufacturers. Regional

investments would be delayed or withheld and less income would be available for the farm household. The decline in household and investment expenditures in the local economy would lead to a further loss in regional employment and income.

The estimated losses in regional employment and income for selected pathway alternatives are presented in Table 17. The regional impacts are related to the expected changes in direct economic costs for power supply, reservoir recreation, navigation, and water supply. Estimated losses are presented for the entire Pacific Northwest region and for the Lower Snake subregion. In the Pacific Northwest, most of the job and income losses are related to the significant increase in regional power costs. In the Lower Snake subregion, income and job losses are related primarily to the increased costs for commodity shipments and the loss of barge traffic during drawdown periods.

Regional Impacts Related to Construction Activities

Many of the SOR alternatives will require physical project modifications and mitigation activities in order to achieve the objectives of the operations strategy. The proposed adaptations include modification of irrigation pumping stations, development of new power stations, improvements to existing adult and juvenile bypass systems, and dam modifications to improve fish passage. The construction activities associated with these mitigation actions and project modifications would provide short-term positive economic benefits to the region through increased employment and earnings opportunities. The expected benefits are short-term in that they are expected to last only throughout the duration of the construction activity. The permanent natural river drawdown and the spillway crest drawdown at Lower Granite reservoir would require five years to implement. A seasonal natural river drawdown would require fifteen years for construction while the spillway crest drawdown at all four Lower Snake projects would require ten years to implement. Employment and income effects related to project construction are not included Table 15, because of the short term duration of these impacts. It is expected that approximately 3,000 construction jobs would be generated during the required project implementation periods. The exception is the seasonal natural river drawdown, where up to 7,000 jobs would be generated during the construction period.

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impacts for M&I pumping were assumed to be related to the losses in household income resulting from increased payments (through taxes or utility rates) required for water supply.

Table C-17
Employment and Income Changes: Pacific Northwest and Lower Snake Subregion

System Alternative	Pacific Northwest Region [b] Employment [c]	Pacific Northwest Region [b] Income [d]	Lower Snake Subregion Employment [c]	Lower Snake Subregion Income [d]
Current Operations [a]	(5,700)	($172)	(300)	($5)
Perm. Nat. River DD	(9,700)	($280)	(3,700)	($76)
Seas. Nat. River DD	(5,600)	($162)	(2,300)	($44)
Spillway Crest DD	(2,300)	($65)	(1,400)	($27)
Lower Granite Only DD	(1,100)	($33)	(200)	($5)
Measured as Changes from Current Operations				
Perm. Nat. River DD	(4,000)	($108)	(3,400)	($71)
Seas. Nat. River DD	100	$10	(2,000)	($39)
Spillway Crest DD	3,400	$107	(1,100)	($22)
Lower Granite Only DD	4,600	$139	100	$0

a/ Regional employment and income effects for current operations and the drawdown alternatives are first shown relative to 1992-1993 system operations to provide a linkage to earlier work prepared for the SOR.

b/ Pacific Northwest region figures exclude impacts related to the drawdown of John Day reservoir to minimum operating pool.

c/ Employment measured as average annual job losses, beginning in the first year of implementation.

d/ Income measured as $1,00,000 in 1996 dollars, beginning in the first year of implementation.

Source: Northwest Economic Associates, *Regional Economic Impacts for the System Operation Review*, October 1995.

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ATTACHMENTS to APPENDIX C

Attachment C1: Project Implementation Costs

Attachment C2: Hydropower Costs

Attachment C3: Recreation Values

Attachment C1: Project Implementation Costs

Table C1-1: Summary of Project Implementation Costs

Table C1-2: Seasonal Natural River Drawdown

Table C1-3: Permanent Natural River Drawdown

Table C1-4: Spillway Crest Drawdown

Table C1-5: Spillway Crest Drawdown at Lower Granite Only

Table C1-6: Surface Collectors, Sluices, and Spillway Baffles

Table C1-7: Miscellaneous Juvenile Bypass Improvements

Table C1-1
Summary of Project Implementation Costs
Cost Figures in $1996, $1000

Description of Alternative	Capital Cost	Average Annual Cost	Years to Implement	Equivalent Annual Cost
Drawdown Alternatives				
Seasonal Natural River Drawdown				
Four Pool	$3,588,000	$515,075	15	$168,117
Two Pool	$1,957,000	$279,860	15	$91,344
Permanent Natural River Drawdown				
Four Pool	$543,000	$53,462	5	$36,810
Two Pool	$271,000	$25,768	5	$17,742
Two Pool (shorter construction)	$271,000	$24,462	3	$19,554
Spillway Crest Drawdown				
Four Pool	$1,033,000	$120,234	10	$56,997
One Pool	$79,000	$8,000	5	$5,000
Juvenile Bypass Improvements				
Surface Collectors				
Screened	$25,000	$2,300	3	$1,900
Unscreened	$18,700	$1,800	3	$1,400
Sluice	$10,000	$1,000	3	$800
Spillway Baffle	$500	$40	1	$40
Extended Length Screens	$26,000	$2,300	3.5	$1,800
Flow Deflectors	25000	2400	5	1600
Stilling Basin Modifications	38000	3800	6.5	2400
Lower Granite Improvements	$22,000	$2,200	5	$1,500

Source: System Configuration Study, Phase I, Appendix A, D, E, and F; System Operation Review, Appendix O.
Personal Communications, Corps of Engineers, Walla Walla District; Harza Northwest, Inc.
Cost estimates revised from original using an interest rate of 7.75% and presented in $1996.

Table C1-2
Project Implementation Costs for a Seasonal Natural River Drawdown
Cost Figures in $1996, $1000

	Lower Granite	Little Goose	Lwr Monumental	Ice Harbor	Total
Construction Costs ($1000, 1996) 1/, 10/					
(contingency rate, percent)					
Real Estate (40)	$142	$142	$142	$142	$568
Project Modifications					
Relocations (40)	$0	$0	$4,595	$1,673	$6,268
Stilling Basin Gates (50)	$115,202	$136,569	$115,202	$0	$366,972
Removal of Dam Non-Overflow Section (50)					
New River Bypass (40)	$511,192	$479,800	$580,736	$400,590	$1,972,319
River Bypass Channel (50)					
Levee (50)					
Powerhouse Modifications (50)					
Misc Dam Modifications (40)	849.9042122	849.9042122	849.9042122	849.9042122	3399.616849
Fish Facilities (50)					
Adult Fish Passage (40)	$93,610	$94,749	$78,474	$4,788	$271,621
Juvenile Fish Passage (40)					
Bank Stabilization (50)					
Riprap Slope Protection (40)	$41,045	$4,694	$10,253	$8,692	$64,684
Project Mitigation					
Irrigation & Water Supply 2/	$3,035	$607	$734	$25,646	$30,023
Recreation Sites 3/					
Resident Fish and Wildlife 3/					
Cultural Resources 3/					
Total Construction Cost	$764,934	$717,270	$790,844	$442,239	$2,715,287
Total Construction & Real Estate	$765,076	$717,412	$790,986	$442,381	$2,715,856
Planning, Engineering, Design (20)	$180,459	$168,514	$186,782	$107,633.70	$643,389.22
Construction Management (10)	$64,659	$60,620	$67,184	$35,990.22	$228,453.14
Total First Cost	$1,010,195	$946,545	$1,044,952	$586,005.25	$3,587,697.86
Annual O&M Costs 4/	$198	$44	$49	$2,102	$2,394
Years for Project Implementation	15	15	15	15	15
Investment & Annual Costs at 7.75 %					
Interest During Construction 5/	$851,406	$797,761	$880,700	$493,893	$3,023,761
Total Investment Costs 6/	$1,861,601	$1,744,307	$1,925,653	$1,079,899	$6,611,459
Annual Investment Cost 7/	$144,357	$135,261	$149,324	$83,740	$512,682
Average Annual Costs 8/	$144,555	$135,305	$149,373	$85,842	$515,075
Average Annual Equivalent Costs 9/	$47,182	$44,163	$48,754	$28,018	$168,117

Source: System Configuration Study, Phase I, Appendix A, Lower Snake Drawdown Options Technical Report.
Notes:
1/ Costs do not include estimated inflation during construction.
2/ Various contingency rates were used. Excludes costs of planning, engineering and design, and construction management.
3/ Costs of impacts have not been estimated.
4/ Annual O&M costs for irrigation and water supply are from SOR Appendix F. The change in O&M costs for the dams has not been estimated.
5/ Interest during construction based on total first cost assuming equal expenditures per year.
6/ The sum of Total First Cost and IDC.
7/ Includes amortization of investment costs over 100 years.
8/ The sum of Annual investment Costs and Annual O&M Costs.
9/ Average annual costs discounted from project on-line date to the base year, 1996.
10/ Costs have been updated from 1992 to 1996 price levels using the ENR-BCI Cost Index.

Table C1-3
Project Implementation Costs for a Permanent Natural River Drawdown
Cost Figures in $1996, $1000

	Lower Granite	Little Goose	Lwr Monumental	Ice Harbor	Total
Construction Costs ($1000, 1996) 1/, 10/					
(contingency rate, percent)					
Real Estate (40)					
Project Modifications					
Relocations (40)					
Stilling Basin Gates (50)					
Removal of Dam Non-Overflow Section (50)	$31,097	$27,191	$33,498	$33,498	$125,284
New River Bypass (40)					
River Bypass Channel (50)	$41,353	$41,353	$20,906	$25,980	$129,593
Levee (50)	$5,177	$5,177	$5,177	$5,177	$20,707
Powerhouse Modifications (50)	$30,822	$30,822	$30,822	$30,822	$123,286
Misc Dam Modifications (40)					
Fish Facilities (50)	$244	$244	$244	$244	$978
Adult Fish Passage (40)					
Juvenile Fish Passage (40)					
Bank Stabilization (50)	$324	$267	$267	$226	$1,084
Riprap Slope Protection (40)					
Project Mitigation					
Irrigation & Water Supply 2/	$3,035	$607	$734	$25,646	$30,023
Recreation Sites 3/					
Resident Fish and Wildlife 3/					
Cultural Resources 3/					
Total Construction Cost	$112,053	$105,661	$91,645	$121,594	$430,956
Total Construction & Real Estate	$112,053	$105,661	$91,645	$121,594	$430,956
Planning, Engineering, Design (20)	$18,463	$17,734	$17,772	$25,246	$79,216
Construction Management (10)	$8,794	$8,475	$7,334	$7,740	$32,342
Total First Cost	$139,310	$131,870	$116,754	$154,580	$542,513
Annual O&M Costs 4/	$199	$85	$49	$2,146	$2,480
Years for Project Implementation	5	5	5	5	5
Investment & Annual Costs at 7.75 %					
Interest During Construction 5/	$29,517	$27,941	$24,738	$32,753	$114,948
Total Investment Costs 6/	$168,827	$159,810	$141,492	$187,332	$657,462
Annual Investment Cost 7/	$13,092	$12,392	$10,972	$14,527	$50,983
Average Annual Costs 8/	$13,291	$12,478	$11,021	$16,673	$53,462
Average Annual Equivalent Costs 9/	$9,151	$8,591	$7,588	$11,479	$36,810

Source: Corps of Engineers, Portland District, personal communication with Tom White.
Notes:
1/ Costs do not include estimated inflation during construction.
2/ Various contingency rates were used. Excludes costs of planning, engineering and design, and construction management.
3/ Costs of impacts have not been estimated.
4/ Annual O&M costs for irrigation and water supply are from SOR Appendix F. The change in O&M costs for the dams has not been estimated.
5/ Interest during construction based on total first cost assuming equal expenditures per year.
6/ The sum of Total First Cost and IDC.
7/ Includes amortization of investment costs over 100 years.
8/ The sum of Annual investment Costs and Annual O&M Costs.
9/ Average annual costs discounted from project on-line date to the base year, 1996.
10/ Costs have been updated from 1992 to 1996 price levels using the ENR-BCI Cost Index.

Table C1-4
Project Implementation Costs for a Seasonal Spillway Crest Drawdown (SOS 6b)
Cost Figures in $1996, $1000

	Lower Granite	Little Goose	Lwr Monumental	Ice Harbor	Total
Construction Costs ($1000, 1996) 1/, 10/					
(contingency rate, percent)					
Real Estate (40)	$127	$127	$127	$127	$508
Project Modifications					
Relocations (40)					
Stilling Basin Gates (50)	$115,202	$136,569	$115,202	$0	$366,972
Removal of Dam Non-Overflow Section (50)					
New River Bypass (40)					
River Bypass Channel (50)					
Levee (50)					
Powerhouse Modifications (50)					
Misc Dam Modifications (40)	$850	$850	$850	$850	$3,400
Fish Facilities (50)					
Adult Fish Passage (40)	$97,736	$97,459	$78,474	$8,852	$282,521
Juvenile Fish Passage (40)	$17,189	$17,189	$17,189	$17,189	$68,755
Bank Stabilization (50)					
Riprap Slope Protection (40)	$32,339	$4,149	$8,306	$5,695	$50,489
Project Mitigation					
Irrigation & Water Supply 2/	$2,570	$246	$345	$13,585	$16,747
Recreation Sites 3/					
Resident Fish and Wildlife 3/					
Cultural Resources 3/					
Total Construction Cost	$265,885	$256,462	$220,366	$46,171	$788,884
Total Construction & Real Estate	$266,027	$256,604	$220,508	$46,313	$789,452
Planning, Engineering, Design (20)	$60,594	$57,855	$49,844	$11,789	$180,081
Construction Management (10)	$21,543	$20,808	$17,912	$2,778	$63,041
Total First Cost	$348,164	$335,268	$288,264	$60,879	$1,032,575
Annual O&M Costs 4/	$168	$17	$24	$1,041	$1,249
Years for Project Implementation	10	10	10	10	10
Investment & Annual Costs at 7.75%					
Interest During Construction 5/	$169,211	$162,943	$140,099	$29,588	$501,841
Total Investment Costs 6/	$517,375	$498,211	$428,363	$90,467	$1,534,416
Annual Investment Cost 7/	$40,120	$38,633	$33,217	$7,015	$118,985
Average Annual Costs 8/	$40,288	$38,650	$33,241	$8,056	$120,234
Average Annual Equivalent Costs 9/	$19,098	$18,322	$15,758	$3,819	$56,997

Source: System Configuration Study, Phase I, Appendix A, Lower Snake Drawdown Options Technical Report.
Notes:
1/ Costs do not include estimated inflation during construction.
2/ Various contingency rates were used. Excludes costs of planning, engineering and design, and construction management.
3/ Costs of impacts have not been estimated.
4/ Annual O&M costs for irrigation and water supply are from SOR Appendix F. The change in O&M costs for the dams has not been estimated.
5/ Interest during construction based on total first cost assuming equal expenditures per year.
6/ The sum of Total First Cost and IDC.
7/ Includes amortization of investment costs over 100 years.
8/ The sum of Annual investment Costs and Annual O&M Costs.
9/ Average annual costs discounted from project on-line date to the base year, 1996.
10/ Costs have been updated from 1992 to 1996 price levels using the ENR-BCI Cost Index.

Table C1-5
Project Implementation Costs for a Seasonal Spillway Crest Drawdown at Lower Granite
Cost Figures in $1996, $1000

	Lower Granite
Construction Costs ($1000, 1996) 1/, 10/	
(contingency rate, percent)	
Real Estate (40)	$142
Project Modifications	
Relocations (40)	
Stilling Basin Gates (50)	
Removal of Dam Non-Overflow Section (50)	
New River Bypass (40)	
River Bypass Channel (50)	
Levee (50)	
Powerhouse Modifications (50)	
Misc Dam Modifications (40)	$850
Fish Facilities (50)	
Adult Fish Passage (40)	$6,288
Juvenile Fish Passage (40)	$17,189
Bank Stabilization (50)	
Riprap Slope Protection (40)	$32,339
Project Mitigation	
Irrigation & Water Supply 2/	$2,295
Recreation Sites 3/	
Resident Fish and Wildlife 3/	
Cultural Resources 3/	
Total Construction Cost	$59,236
Total Construction & Real Estate	$59,378
Planning, Engineering, Design (20)	$14,304
Construction Management (10)	$4,874
Total First Cost	$78,555
Annual O&M Costs 4/	$168
Years for Project Implementation	5
Investment & Annual Costs at 7.75%	
Interest During Construction 5/	$16,644
Total Investment Costs 6/	$95,200
Annual Investment Cost 7/	$7,382
Average Annual Costs 8/	$7,550
Average Annual Equivalent Costs 9/	$5,198

Source: System Configuration Study, Phase I, Appendix A, Lower Snake Drawdown Options Technical Report.
Notes:
1/ Costs do not include estimated inflation during construction.
2/ Various contingency rates used. Excludes costs of planning, engineering and design, and construction management.
3/ Costs of impacts have not been estimated.
4/ Annual O&M costs for irrigation and water supply are from SOR Appendix F.
The change in O&M costs for the dams has not been estimated.
5/ Interest during construction based on total first cost assuming equal expenditures per year.
6/ The sum of Total First Cost and IDC.
7/ Includes amortization of investment costs over 100 years.
8/ The sum of Annual investment Costs and Annual O&M Costs.
9/ Average annual costs discounted from project on-line date to the base year, 1996.
10/ Costs have been updated from 1992 to 1996 price levels using the ENR-BCI Cost Index.

Table C1-6
Project Implementation Costs for Surface Collectors, Sluices, and Spillway Baffles
Cost Figures in $1996, $1000

	Screened Surface Collector	Unscreened Surface Collector	Sluice	Spillway Baffle
Cost figures in 1996, $1000				
Construction Costs 1/	$25,000	$18,700	$10,000	$500
Annual O&M Costs	$146	$146	$146	$0
Years for Project Implementation	3	3	3	1
Investment & Annual Costs at 7.75%				
Interest During Construction 2/	$3,014	$2,254	$1,206	$19
Total Investment Costs 3/	$28,014	$20,954	$11,206	$519
Annual Investment Cost 4/	$2,172	$1,625	$869	$40
Average Annual Costs 5/	$2,318	$1,771	$1,015	$40
Average Annual Equivalent Costs 6/	$1,853	$1,416	$811	$37

Source: Surface Collectors and Sluice -- Personal communication, Corps of Engineers, Walla Walla District, Spring 1996.
Spillway Baffles -- Personal communication, Harza Northwest, Inc., Spring 1996.

Notes:
1/ Costs do not include estimated inflation during construction.
2/ Interest during construction based on total first cost assuming equal expenditures per year.
3/ The sum of Total First Cost and IDC.
4/ Includes amortization of investment costs over 100 years.
5/ The sum of Annual investment Costs and Annual O&M Costs.
6/ Average annual costs discounted from project on-line date to the base year, 1996.

Table C1-7
Project Implementation Costs for Miscellaneous Juvenile Bypass System Improvements
Cost Figures in $1996, $1000

	Short-Haul Barging	Ext Length Screens	Lwr Granite Facility Imprv	Flow Deflector	Elevated Stilling Basin
Cost figures in 1996, $1000					
Construction Costs 1/, 7/	$10,560	$25,622	$22,047	$25,223	$38,493
Annual O&M Costs	$2,010	$40	$82	$0	$0
Years for Project Implementation	3.5	3.5	5	5	6.5
Investment & Annual Costs at 7.75%					
Interest During Construction 2/	$1,477	$3,583	$4,671	$5,344	$10,984
Total Investment Costs 3/	$12,037	$29,205	$26,718	$30,568	$49,476
Annual Investment Cost 4/	$933	$2,265	$2,072	$2,370	$3,837
Average Annual Costs 5/	$2,944	$2,305	$2,154	$2,370	$3,837
Average Annual Equivalent Costs 6/	$2,267	$1,775	$1,483	$1,632	$2,362

Source: System Configuration Study, Phase I, Appendix E, Improvements to the Existing System Technical Report.
System Configuration Study, Phase I, Appendix F, System Improvements, Technical Report, Lower Columbia River.

Notes:

1/ Costs do not include estimated inflation during construction.
2/ Interest during construction based on total first cost assuming equal expenditures per year.
3/ The sum of Total First Cost and IDC.
4/ Includes amortization of investment costs over 100 years.
5/ The sum of Annual investment Costs and Annual O&M Costs.
6/ Average annual costs discounted from project on-line date to the base year, 1996.
7/ Costs have been updated from 1992 to 1996 price levels using the ENR-BCI Cost Index.

Attachment C2: Hydropower Costs

Table C2-1: Regional Power Costs for Selected SOR Alternatives

Table C2-2: Hydropower Costs Associated with Selected Bypass Improvements

Table C2-1
Regional Power Costs for Selected SOR Alternatives
Cost Figure in $1996, $1,000,000

Regional Power Costs	1992-93 Operations	SOR Pref. Alternative	Seas. Nat. River DD	Perm. Nat. River DD	Seas. Splway Crest DD	Lwr Grnt Only DD
(SOR Appendix table reference in parentheses)						
Energy Produced, aMW (I4-5)	16,771	16,464	15,943	15,826	16,494	16,682
Total '96 Costs $96 (I4-15)	$1,026	$1,162	$1,129	$1,165	$1,069	$1,048
'96 Energy Costs $96 (I4-8)	$1,026	$1,143	$1,108	$1,132	$1,054	$1,038
'96 Changes in Capacity Costs $96 (I5-3)	$0	$19	$21	$32	$14	$9
	$0	$0	$0	$0	$0	$0
Total '96 Costs	$1,026	$1,161	$1,128	$1,163	$1,068	$1,046
Total '04 Costs	$1,507	$1,676	$1,682	$1,755	$1,569	$1,532
Net '96 Costs after Load Adj. (O4-44)	$1,025	$1,146	$1,109	$1,141	$1,061	$1,044
Net '04 Costs after Load Adj. (O4-44)	$1,507	$1,657	$1,653	$1,720	$1,558	$1,528
Average Annual Equivalent Costs	$1,349	$1,465	$1,397	$1,491	$1,374	$1,364
Changes Measured from SOS 2c						
Energy Produced, aMW (I4-5)	0	(307)	(828)	(945)	(277)	(89)
Total '96 Costs $96 (I4-15)	$0	$136	$103	$139	$43	$22
'96 Energy Costs $96 (I4-8)	$0	$117	$82	$106	$28	$12
'96 Changes in Capacity Costs $96 (I5-3)	$0	$19	$21	$32	$14	$9
Total '96 Costs	$0	$135	$102	$137	$42	$20
Total '04 Costs	$0	$169	$175	$248	$62	$25
Net '96 Costs after Load Adj.	$0	$121	$85	$117	$36	$19
Net '04 Costs after Load Adj.	$0	$150	$146	$213	$51	$21
Implementation Date	1995	1998	2010	2000	2005	2000
Average Annual Equivalent Costs	0	116	48	141	24	15
Changes Measured from SOS PA						
Energy Produced, aMW (I4-5)	307	0	(521)	(638)	30	218
Total '96 Costs $96 (I4-15)	($136)	$0	($33)	$3	($93)	($114)
'96 Energy Costs $96 (I4-8)	($117)	$0	($35)	($11)	($89)	($105)
'96 Changes in Capacity Costs $96 (I5-3)	($19)	$0	$2	$13	($5)	($10)
Total '96 Costs	($135)	$0	($33)	$2	($93)	($115)
Total '04 Costs	($169)	$0	$5	$78	($107)	($145)
Net '96 Costs after Load Adj.	($121)	$0	($36)	($4)	($85)	($102)
Net '04 Costs after Load Adj.	($150)	$0	($4)	$63	($99)	($129)
Implementation Date	$1,995	$1,998	$2,010	$2,000	$2,005	$2,000
Average Annual Equivalent Costs	($116)	$0	($69)	$25	($92)	($102)

Source: System Operation Review, Final EIS, Appendix I, Power
System Operation Review, Final EIS, Appendix O, Economic and Social Impacts
Prices updated to 1996 using the GDP implicit price deflator.

Table C2-1, continued
Regional Power Costs for Selected SOR Alternatives
Cost Figure in $1996, $1,000,000

Regional Power Costs	1992-93 Operations	SOR Pref. Alternative	DFOP	Adaptive Management	Idaho Plan
(SOR Appendix table reference in parentheses)					
Energy Produced, aMW (I4-5)	16,771	16,464	15,676	16,160	16,042
Total '96 Costs $96 (I4-15)	$1,026	$1,162	$1,328	$1,246	$1,194
'96 Energy Costs $96 (I4-8)	$1,026	$1,143	$1,268	$1,226	$1,167
'96 Changes in Capacity Costs $96 (I5-3)	$0	$19	$60	$20	$28
Total '96 Costs	$1,026	$1,161	$1,326	$1,244	$1,193
Total '04 Costs	$1,507	$1,676	$1,893	$1,776	$1,737
Net '96 Costs after Load Adj. (O4-44)	$1,025	$1,146	$1,292	$1,218	$1,174
Net '04 Costs after Load Adj. (O4-44)	$1,507	$1,657	$1,853	$1,743	$1,710
Average Annual Equivalent Costs	$1,349	$1,465	$1,513	$1,571	$1,445
Changes Measured from SOS 2c					
Energy Produced, aMW (I4-5)	0	(307)	(1,095)	(611)	(729)
Total '96 Costs $96 (I4-15)	$0	$136	$302	$220	$168
'96 Energy Costs $96 (I4-8)	$0	$117	$242	$200	$141
'96 Changes in Capacity Costs $96 (I5-3)	$0	$19	$60	$20	$28
Total '96 Costs	$0	$135	$300	$218	$167
Total '04 Costs	$0	$169	$386	$269	$230
Net '96 Costs after Load Adj.	$0	$121	$267	$193	$149
Net '04 Costs after Load Adj.	$0	$150	$346	$236	$203
Implementation Date	1995	1998	2005	1995	2005
Average Annual Equivalent Costs	$0	$116	$164	$222	$96
Changes Measured from SOS PA					
Energy Produced, aMW (I4-5)	307	0	(788)	(304)	(422)
Total '96 Costs $96 (I4-15)	($136)	$0	$166	$84	$32
'96 Energy Costs $96 (I4-8)	($117)	$0	$125	$83	$24
'96 Changes in Capacity Costs $96 (I5-3)	($19)	$0	$41	$1	$9
Total '96 Costs	($135)	$0	$165	$84	$32
Total '04 Costs	($169)	$0	$217	$100	$61
Net '96 Costs after Load Adj.	($121)	$0	$146	$72	$28
Net '04 Costs after Load Adj.	($150)	$0	$196	$86	$53
Implementation Date	$1,995	$1,998	$2,005	$1,995	$2,005
Average Annual Equivalent Costs	($116)	$0	$48	$106	($20)

Source: System Operation Review, Final EIS, Appendix I, Power
System Operation Review, Final EIS, Appendix O, Economic and Social Impacts
Prices updated to 1996 using the GDP implicit price deflator.

Table C2-2
Hydropower Costs Associated with Bypass Improvements
Flow targets based on 1995 NMFS Biological Opinion

Operating Characteristics for Lower Granite Dam

Generating Head (ft):	100
Generating Efficiency:	85%
Spill Durartion (hrs/day):	12

Computations

MW = (Flow*Head*Efficiency/11.8)/1000
MWh = MW * (hrs/day) * # days
Revenues = MWh * $/MWh

Estimated Power Revenues Lost Spill **(assumes 70% FPE for juvenile bypass system)**

Month	LGr Flow Target (cfs)	Spill Requirement Share	Spill Requirement cfs	Lost Hydrogeneration MW	Lost Hydrogeneration MWh	Non-Firm $/MWh	Lost Revenues
Apr 16 - Apr 30	100,000	31%	31,000	223	40,190	$15	$602,850
May 1 - May 31	100,000	31%	31,000	223	83,070	$15	$1,246,050
Jun 1 - Jun 20	100,000	31%	31,000	223	53,590	$15	$803,850
Jun 21 - Jun 30	55,000	0%	0	0	0	$15	$0
Jul 1 - Jul 31	55,000	0%	0	0	0	$15	$0
Aug 1 - Aug 31	55,000	0%	0	0	0	$16	$0
						Total	$2,652,750

Estimated Power Revenues Lost with Surface Collector

Month	LGr Flow Target (cfs)	Spill Requirement Share	Spill Requirement cfs	Lost Hydrogeneration MW	Lost Hydrogeneration MWh	Non-Firm $/MWh	Lost Revenues
Apr 16 - Apr 30	100,000	10%	10,000	72	25,930	$15	$388,950
May 1 - May 31	100,000	10%	10,000	72	53,590	$15	$803,850
Jun 1 - Jun 20	100,000	10%	10,000	72	34,580	$15	$518,700
Jun 21 - Jun 30	55,000	18%	10,000	72	17,290	$15	$259,350
Jul 1 - Jul 31	55,000	18%	10,000	72	53,590	$15	$803,850
Aug 1 - Aug 31	55,000	18%	10,000	72	53,590	$16	$857,440
						Total	$3,632,140

Estimated Power Revenues Lost with Sluice

Month	LGr Flow Target (cfs)	Spill Requirement Share	Spill Requirement cfs	Lost Hydrogeneration MW	Lost Hydrogeneration MWh	Non-Firm $/MWh	Lost Revenues
Apr 16 - Apr 30	100,000	3%	3,000.00	22	7,780	$15	$116,700
May 1 - May 31	100,000	3%	3,000.00	22	16,080	$15	$241,200
Jun 1 - Jun 20	100,000	3%	3,000.00	22	10,370	$15	$155,550
Jun 21 - Jun 30	55,000	5%	3,000.00	22	5,190	$15	$77,850
Jul 1 - Jul 31	55,000	5%	3,000.00	22	16,080	$15	$241,200
Aug 1 - Aug 31	55,000	5%	3,000.00	22	16,080	$16	$257,280
						Total	$1,089,780

Table C2-2, continued
Hydropower Costs Associated with Bypass Improvements
Flow targets based on 1995 NMFS Biological Opinion

Operating Characteristics for Lower Granite Dam

Generating Head (ft):	100
Generating Efficiency:	85%
Spill Durartion (hrs/day):	12

Computations

MW = (Flow*Head*Efficiency/11.8)/1000
MWh = MW * (hrs/day) * # days
Revenues = MWh * $/MWh

Estimated Power Revenue Lost with Spillway Baffles

Month	LGr Flow Target (cfs)	Spill Requirement Share	Spill Requirement cfs	Lost Hydrogeneration MW	Lost Hydrogeneration MWh	Non-Firm $/MWh	Lost Revenues
Optimistic Fish-Spill Ratio (20:1)		*Requires Baffle in One Bay*					
Apr 16 - Apr 30	100,000	1.5%	1,500	11	1,945	$15	$29,175
May 1 - May 31	100,000	1.5%	1,500	11	4,019	$15	$60,285
Jun 1 - Jun 20	100,000	1.5%	1,500	11	2,593	$15	$38,895
Jun 21 - Jun 30	55,000	1.5%	825	6	713	$15	$10,695
Jul 1 - Jul 31	55,000	1.5%	825	6	2,211	$15	$33,165
Aug 1 - Aug 31	55,000	1.5%	825	6	2,211	$16	$35,376
						Total	$207,591
Average Fish-Spill Ratio (10:1)		*Requires Baffles in Two Bays*					
Apr 16 - Apr 30	100,000	3%	3,000	22	3,890	$15	$58,350
May 1 - May 31	100,000	3%	3,000	22	8,039	$15	$120,585
Jun 1 - Jun 20	100,000	3%	3,000	22	5,186	$15	$77,790
Jun 21 - Jun 30	55,000	3%	1,650	12	1,426	$15	$21,390
Jul 1 - Jul 31	55,000	3%	1,650	12	4,421	$15	$66,315
Aug 1 - Aug 31	55,000	3%	1,650	12	4,421	$16	$70,736
						Total	$415,166
Pessimistic Fish-Spill Ratio (5:1)		*Requires Baffles in Three Bays*					
Apr 16 - Apr 30	100,000	6%	6000	43	7,780.00	$15	$116,700
May 1 - May 31	100,000	6%	6000	43	16,078.00	$15	$241,170
Jun 1 - Jun 20	100,000	6%	6000	43	10,373.00	$15	$155,595
Jun 21 - Jun 30	55,000	6%	3300	24	2,853.00	$15	$42,795
Jul 1 - Jul 31	55,000	6%	3300	24	8,843.00	$15	$132,645
Aug 1 - Aug 31	55,000	6%	3300	24	8,843.00	$16	$141,488
						Total	$830,393

Attachment C3: Recreation Values

Table C3-1
Annual Recreation Days Based on an Average Water Year

Federal Project	Preferred Alternative	1992-93 Operations	Seas. Nat. River DD	Perm. Nat. River DD	Seas. Splwy Crest DD	Lwr GRnt Only DD
Upper Columbia Projects						
Hungry Horse Dam & Lake	133,530	129,257	126,532	126,533	126,533	126,533
Libby Dam/Lake Koocanusa	601,640	607,247	602,870	602,871	602,871	602,871
Kootenai River	24,960	35,636	34,989	34,989	34,989	34,989
Albeni Falls Dam/Lake Pend Orielle	1,243,190	1,222,511	1,217,773	1,217,773	1,217,773	1,217,773
Columbia River Canada	39,131	41,584	41,506	41,515	41,506	41,506
Grand Coulee Dam/Lake Roosevelt	1,612,827	1,670,069	1,665,931	1,665,931	1,665,931	1,665,931
Chief Joseph Dam/Rufus Woods Lake	47,900	47,900	47,900	47,900	47,900	47,900
Mid Columbia PUDs	1,481,900	1,481,900	1,481,900	1,481,900	1,481,900	1,481,900
Subtotal Upper Columbia	5,185,078	5,236,104	5,219,401	5,219,412	5,219,403	5,219,403
Lower Snake Projects						
Snake River Hells Canyon	43,500	43,500	43,500	43,500	43,500	43,500
Dworshak Dam & Lake	149,645	201,413	213,711	226,932	198,854	198,854
Clearwater River	151,296	128,224	126,711	141,589	133,905	133,905
Lower Granite Dam & Lake	1,673,460	1,662,699	859,290	652,290	1,250,024	1,250,024
Little Goose Dam/Lake Bryan	242,655	240,402	92,671	71,143	164,402	240,402
Lower Monumental Dam/Lake West	138,766	137,598	57,577	44,052	96,492	137,598
Ice Harbor Dam/Lake Sacajawea	519,212	514,730	164,147	127,270	335,312	514,730
Subtotal Lower Snake	2,918,534	2,928,566	1,557,607	1,306,776	2,222,489	2,519,013
Lower Columbia Projects						
McNary Dam/Lake Wallula	2,747,500	2,747,500	2,747,500	2,747,500	2,747,500	2,747,500
John Day Dam/Lake Umatilla	1,502,081	2,555,389	2,120,958	2,120,958	2,120,958	2,120,958
The Dalles Dam/Lake Celilo	1,411,300	1,411,300	1,411,300	1,411,300	1,411,300	1,411,300
Bonneville Dam & Lake	3,164,600	3,164,600	3,164,600	3,164,600	3,164,600	3,164,600
Subtotal Lower Columbia	8,825,481	9,878,789	9,444,358	9,444,358	9,444,358	9,444,358
Region Total	16,929,093	18,043,459	16,221,366	15,970,546	16,886,250	17,182,774

Source: System Operation Review, Final EIS, Appendix J, Recreation, Table 5-1.

Table C3-1, continued
Annual Recreation Days Based on an Average Water Year

Federal Project	DFOP	Adaptive Mngt.	Idaho Plan	Pre-ESA	Optimum Load
Upper Columbia Projects					
Hungry Horse Dam & Lake	91,036	135,367	152,580	128,303	125,670
Libby Dam/Lake Koocanusa	546,186	596,840	618,419	604,590	603,795
Kootenai River	14,270	28,942	33,881	34,316	34,912
Albeni Falls Dam/Lake Pend Orielle	1,001,121	1,148,023	1,187,905	1,215,923	1,216,917
Columbia River Canada	40,723	39,405	40,199	40,653	41,520
Grand Coulee Dam/Lake Roosevelt	1,257,182	1,482,095	1,570,658	1,630,971	1,637,181
Chief Joseph Dam/Rufus Woods Lake	47,900	47,900	47,900	47,900	47,900
Mid Columbia PUDs	1,481,900	1,481,900	1,481,900	1,481,900	1,481,900
Subtotal Upper Columbia	4,480,318	4,960,472	5,133,442	5,184,556	5,189,795
Lower Snake Projects					
Snake River Hells Canyon	43,500	43,500	43,500	43,500	43,500
Dworshak Dam & Lake	180,361	133,202	183,092	182,676	185,625
Clearwater River	136,247	135,271	143,327	109,147	105,285
Lower Granite Dam & Lake	1,175,338	1,618,319	1,485,478	1,653,879	1,687,100
Little Goose Dam/Lake Bryan	151,909	233,075	203,317	244,797	244,861
Lower Monumental Dam/Lake West	89,356	133,421	119,271	140,009	140,052
Ice Harbor Dam/Lake Sacajawea	301,583	494,838	449,605	525,658	525,916
Subtotal Lower Snake	2,078,294	2,791,626	2,627,590	2,899,666	2,932,339
Lower Columbia Projects					
McNary Dam/Lake Wallula	2,747,500	2,747,500	2,747,500	2,747,500	2,747,500
John Day Dam/Lake Umatilla	2,103,849	2,555,389	2,068,283	2,860,009	2,860,009
The Dalles Dam/Lake Celilo	1,411,300	1,411,300	1,411,300	1,411,300	1,411,300
Bonneville Dam & Lake	3,164,600	3,164,600	3,164,600	3,164,600	3,164,600
Subtotal Lower Columbia	9,427,249	9,878,789	9,391,683	10,183,409	10,183,409
Region Total	15,985,861	17,630,887	17,152,715	18,267,631	18,305,543

Source: System Operation Review, Final EIS, Appendix J, Recreation, Table 5-1.

Table C3-2
Change in Recreation Visitor Days from SOS PA

Federal Project	1992-93 Operations	Seas. Nat. River DD	Perm. Nat. River DD	Seas. Splwy Crest DD	Lwr GRnt Only DD
Upper Columbia Projects					
Hungry Horse Dam & Lake	(4,273)	(6,998)	(6,997)	(6,997)	(6,997)
Libby Dam/Lake Koocanusa	5,607	1,230	1,231	1,231	1,231
Kootenai River	10,676	10,029	10,029	10,029	10,029
Albeni Falls Dam/Lake Pend Orielle	(20,679)	(25,417)	(25,417)	(25,417)	(25,417)
Columbia River Canada	2,453	2,375	2,384	2,375	2,375
Grand Coulee Dam/Lake Roosevelt	57,242	53,104	53,104	53,104	53,104
Chief Joseph Dam/Rufus Woods Lake					
Mid Columbia PUDs					
Subtotal Upper Columbia	51,026	34,323	34,334	34,325	34,325
Lower Snake Projects					
Snake River Hells Canyon					
Dworshak Dam & Lake	51,768	64,066	77,287	49,209	49,209
Clearwater River	(23,072)	(24,585)	(9,707)	(17,391)	(17,391)
Lower Granite Dam & Lake	(10,761)	(814,170)	(1,021,170)	(423,436)	(423,436)
Little Goose Dam/Lake Bryan	(2,253)	(149,984)	(171,512)	(78,253)	(2,253)
Lower Monumental Dam/Lake West	(1,168)	(81,189)	(94,714)	(42,274)	(1,168)
Ice Harbor Dam/Lake Sacajawea	(4,482)	(355,065)	(391,942)	(183,900)	(4,482)
Subtotal Lower Snake	10,032	(1,360,927)	(1,611,758)	(696,045)	(399,521)
Lower Columbia Projects					
McNary Dam/Lake Wallula	0	0	0	0	0
John Day Dam/Lake Umatilla	1,053,308	618,877	618,877	618,877	618,877
The Dalles Dam/Lake Celilo	0	0	0	0	0
Bonneville Dam & Lake	0	0	0	0	0
Subtotal Lower Columbia	1,053,308	618,877	618,877	618,877	618,877
Region Total	1,114,366	(707,727)	(958,547)	(42,843)	253,681

Table C3-2, continued
Change in Recreation Visitor Days from SOS PA

Federal Project	DFOP	Adaptive Mngt.	Idaho Plan	Pre-ESA	Optimum Load
Upper Columbia Projects					
Hungry Horse Dam & Lake	(42,494)	1,837	19,050	(5,227)	(7,860)
Libby Dam/Lake Koocanusa	(55,454)	(4,800)	16,779	2,950	2,155
Kootenai River	(10,690)	3,982	8,921	9,356	9,952
Albeni Falls Dam/Lake Pend Orielle	(242,069)	(95,167)	(55,285)	(27,267)	(26,273)
Columbia River Canada	1,592	274	1,068	1,522	2,389
Grand Coulee Dam/Lake Roosevelt	(355,645)	(130,732)	(42,169)	18,144	24,354
Chief Joseph Dam/Rufus Woods Lake					
Mid Columbia PUDs					
Subtotal Upper Columbia	(704,760)	(224,606)	(51,636)	(522)	4,717
Lower Snake Projects					
Snake River Hells Canyon					
Dworshak Dam & Lake	30,716	(16,443)	33,447	33,031	35,980
Clearwater River	(15,049)	(16,025)	(7,969)	(42,149)	(46,011)
Lower Granite Dam & Lake	(498,122)	(55,141)	(187,982)	(19,581)	13,640
Little Goose Dam/Lake Bryan	(90,746)	(9,580)	(39,338)	2,142	2,206
Lower Monumental Dam/Lake West	(49,410)	(5,345)	(19,495)	1,243	1,286
Ice Harbor Dam/Lake Sacajawea	(217,629)	(24,374)	(69,607)	6,446	6,704
Subtotal Lower Snake	(840,240)	(126,908)	(290,944)	(18,868)	13,805
Lower Columbia Projects					
McNary Dam/Lake Wallula	0	0	0	0	0
John Day Dam/Lake Umatilla	601,768	1,053,308	566,202	1,357,928	1,357,928
The Dalles Dam/Lake Celilo	0	0	0	0	0
Bonneville Dam & Lake	0	0	0	0	0
Subtotal Lower Columbia	601,768	1,053,308	566,202	1,357,928	1,357,928
Region Total	(943,232)	701,794	223,622	1,338,538	1,376,450

Table C3-3
Average Annual Recreation Values
Values in $1996, $1,000

Federal Project	1992-93 Operations	Preferred Alternative	Seas. Nat. River DD	Perm. Nat. River DD	Seas. Splwy Crest DD	Lwr GRnt Only DD
Upper Columbia Projects						
Hungry Horse Dam & Lake	8,057	8,468	7,853	7,853	7,853	7,853
Libby Dam/Lake Koocanusa	4,538	4,457	4,475	4,475	4,475	4,475
Kootenai River	588	401	575	575	575	575
Albeni Falls Dam/Lake Pend Orielle	39,565	40,424	39,371	39,371	39,371	39,371
Grand Coulee Dam/Lake Roosevelt	135,976	128,300	135,440	135,440	135,44C	135,440
Subtotal Upper Columbia	188,724	182,050	187,713	187,713	187,713	187,713
Lower Snake Projects						
Dworshak Dam & Lake	15,102	8,484	16,639	18,227	14,594	14,594
Clearwater River	111	313	133	235	144	144
Lower Granite Dam & Lake	61,078	61,803	2,310	2,310	29,010	29,010
Little Goose Dam/Lake Bryan	11,227	11,380	422	422	5,324	11,227
Lower Monumental Dam/Lake West	6,083	6,163	230	230	2,890	6,083
Ice Harbor Dam/Lake Sacajawea	26,677	26,981	1,020	1,020	12,722	26,677
Subtotal Lower Snake	120,278	115,123	20,754	22,443	64,684	87,736
Lower Columbia Projects						
John Day Dam/Lake Umatilla	42,626	22,016	24,170	24,170	24,170	24,170
Subtotal Lower Columbia	42,626	22,016	24,170	24,170	24,170	24,170
Region Total	351,628	319,189	232,638	234,327	276,567	299,619

Source: System Operation Review, Final EIS, Appendix O, Economic and Social Impact, Table 4-49.
Values updated using the Consumer Price Index-U for all commodities.

Table C3-3, continued
Average Annual Recreation Values
Values in $1996, $1,000

Federal Project	DFOP	Adaptive Mngt.	Idaho Plan	Pre-ESA	Optimum Load
Upper Columbia Projects					
Hungry Horse Dam & Lake	5,151	8,596	9,930	7,993	7,786
Libby Dam/Lake Koocanusa	3,654	4,388	4,699	4,499	4,488
Kootenai River	214	466	556	563	573
Albeni Falls Dam/Lake Pend Orielle	30,519	36,523	38,153	39,296	39,336
Grand Coulee Dam/Lake Roosevelt	85,685	111,580	122,796	131,322	132,093
Subtotal Upper Columbia	125,223	161,552	176,135	183,674	184,276
Lower Snake Projects					
Dworshak Dam & Lake	12,790	8,063	12,793	12,694	13,104
Clearwater River	218	210	284	71	63
Lower Granite Dam & Lake	24,055	57,884	47,561	60,499	63,101
Little Goose Dam/Lake Bryan	4,495	10,700	8,388	11,593	11,598
Lower Monumental Dam/Lake West	2,416	5,783	4,685	6,284	6,287
Ice Harbor Dam/Lake Sacajawea	10,483	25,247	21,738	27,583	27,601
Subtotal Lower Snake	54,457	107,887	95,449	118,724	121,753
Lower Columbia Projects					
John Day Dam/Lake Umatilla	23,727	42,626	22,016	54,470	54,470
Subtotal Lower Columbia	23,727	42,626	22,016	54,470	54,470
Region Total	203,407	312,065	293,600	356,868	360,498

Source: System Operation Review, Final EIS, Appendix O, Economic and Social Impact, Table 4-49.
Values updated using the Consumer Price Index-U for all commodities.

Table C3-4
Regional Summary of Recreation Values

Recreation Values: Average Annual Equivalents, by region
$1996, $1000

	Upper Columbia	Lower Snake	Lower Columbia	Region Total
1992-93 Oper.	188,724	120,278	42,626	351,628
Pref. Alternative	183,390	116,158	26,153	325,701
Seas. NR DD	188,395	87,833	36,609	312,836
Perm. NR DD	188,028	52,935	29,922	270,885
Seas SC DD	188,245	93,940	33,882	316,068
LG Only DD	188,028	97,878	29,922	315,828
DFOP	158,640	89,095	33,672	281,408
Adptv Mngt	161,552	107,887	42,626	312,065
Idaho Plan	182,760	108,515	32,862	324,137
Pre-ESA	183,674	118,724	54,470	356,868
Optimum Load	184,276	121,753	54,470	360,498

Recreation Values without John Day MOP

	Upper Columbia	Lower Snake	Lower Columbia	Region Total
1992-93 Oper.	188,724	120,278	42,626	351,628
Pref. Alternative	183,390	116,158	42,626	342,173
Seas. NR DD	188,395	87,833	42,626	318,853
Perm. NR DD	188,028	52,935	42,626	283,589
Seas SC DD	188,245	93,940	42,626	324,811
LG Only DD	188,028	97,878	42,626	328,532
DFOP	158,640	89,095	42,626	290,362
Adptv Mngt	161,552	107,887	42,626	312,065
Idaho Plan	182,760	108,515	42,626	333,901
Pre-ESA	183,674	118,724	54,470	356,868
Optimum Load	184,276	121,753	54,470	360,498

Measured as Changes from SOS PA

	Upper Columbia	Lower Snake	Lower Columbia	Region Total
1992-93 Oper.	5,334	4,120	16,473	25,927
Pref. Alternative	0	0	0	0
Seas. NR DD	5,005	(28,325)	10,456	(12,864)
Perm. NR DD	4,639	(63,223)	3,769	(54,816)
Seas SC DD	4,856	(22,218)	7,730	(9,633)
LG Only DD	4,639	(18,280)	3,769	(9,873)
DFOP	(24,749)	(27,063)	7,519	(44,293)
Adptv Mngt	(21,837)	(8,271)	16,473	(13,636)
Idaho Plan	(630)	(7,643)	6,709	(1,564)
Pre-ESA	284	2,566	28,317	31,167
Optimum Load	886	5,595	28,317	34,797

Measured as Changes from SOS PA

	Upper Columbia	Lower Snake	Lower Columbia	Region Total
1992-93 Oper.	5,334	4,120	0	9,455
Pref. Alternative	0	0	0	0
Seas. NR DD	5,005	(28,325)	0	(23,320)
Perm. NR DD	4,639	(63,223)	0	(58,585)
Seas SC DD	4,856	(22,218)	0	(17,362)
LG Only DD	4,639	(18,280)	0	(13,641)
DFOP	(24,749)	(27,063)	0	(51,812)
Adptv Mngt	(21,837)	(8,271)	0	(30,108)
Idaho Plan	(630)	(7,643)	0	(8,272)
Pre-ESA	284	2,566	11,844	14,695
Optimum Load	886	5,595	11,844	18,325

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REFERENCES

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Errata

P. 1-line 1 change ***Fishery*** to ***Fisheries***

P. 1-13, Figure 1-7. Insert the word ***increase*** between *dam* and *juvenile* in the box of Potential Benefit of Transportation

P. 6-9. Line 12. Change ***1195*** BiOp to ***1995*** BiOp

P 7-20. Tool Costs. Line 4 and Line 5 should read: ***...could construct and operate new surface collectors at four lower Snake River projects.***

Using the data in Figure 7-5, costs...

Page 10-10. Figure 10-2. Change Header on Top of Figure from ***Overall Survival*** to ***In-river Survival***. Change Ice Harbor assumptions from ***.25* to *2.25*** and Lower Columbia assumptions from ***.09 to 2.09*** in the far left column.